How do Solar Portable Lighting (SPL) products affect the amount of time spent on educational activities in Rwanda?

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Abstract

The provision of modern energy services is a fundamental development goal. Rwanda, like many other developing nations in Sub-Saharan Africa (SSA), faces ongoing challenges to energy provision to rural, decentralized, populations. Like many SSA countries, the provision of modern energy services in Rwanda is linked to poverty alleviation goals through economic stimulation and the provision of a healthy and safe environment for rural populations. However, the implementation and dissemination of effective technologies that provide electrification for rural populations in developing nations, which are central to the Millennium Development Goals (MDGs), remains a major challenge.

This study explores the potential of four diverse Solar Portable Light (SPL) products in meeting lighting demands of rural and decentralized populations in Rwanda, with particular focus on their impact on time spent on educational activity. It also looks at the impact these products have on household income and welfare.

The key findings to the central question posed in this study reveal that time spent on educational activities varies according to the household (teacher or student) and the product in question. Overall, the SPL products do show a significant impact on time spent on educational activities for students, whereas results from teacher households are dependent on the product.

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List of Acronyms

BoP - Bottom of Pyramid

IEA – International Energy Agency

IMF – International Monetary Fund

FOB - Freight on Board

GEF – Global Environment Fund

GIZ - Gesellschaft für Internationale Zusammenarbeit

GoR - Government of Rwanda

LED - Light-emitting Diode

MDG – Millennium Development Goal

MINEDUC – Ministry of Education

MININFRA – Ministry of Infrastructure

MNE – Multinational Enterprise

NGO – Non-government organization

OECD – Organization for Economic Co-operation and Development

RURA – Rwanda Utilities Regulatory Agency

SACCO - Saving and Credit Co-operative

SEDP - Sustainable Energy Development Project

SHS – Solar Home System

SPL – Solar Portable Light

SSA – Sub-Saharan Africa

UNDP – Unite Nations Development Programme

VAT- Value-added tax

WHO – World Health Organization

1 Introduction

1.1 Off grid-lighting as an emergent market

Approximately 1.6 billion people in the world today do not have access to electricity (Modi, 2005), with up to 580 million individuals in Sub-Saharan Africa (SSA) (IEA, 2010). Access to clean, affordable and reliable modern energy services is an essential input for socio-economic development and poverty alleviation (Johansson et al., 2002). The term "energy access" is described by Modi et al (2005) as the services that energy (and energy appliances) offer including, "lighting, heating for cooking and space heating, power for transport, water pumping, grinding, and numerous other services that fuels, electricity, and mechanical power make possible". Although access to modern energy services is a crucial basis for socio-economic development, traditional biomass resources still provide over 90% of household energy needs in most SSA nations (Bailis et al., 2007).

Furthermore, lighting often represents the most expensive energy item amongst rural household expenditure, accounting for 10-15% of total household income (World Bank, 2007). Low-income rural households in SSA rely on expensive and inconvenient forms of lighting such as low-efficiency kerosene lanterns or candles, or have no access to light at all (IEA, 2010). Kerosene, one of the most widespread source of lighting fuel in Africa, is expensive and poses well-documented adverse health, safety and environmental risks (World Bank, 2010). From a health perspective, there are a number of adverse effects associated with kerosene use. For example, studies have found some of the compounds in kerosene to be carcinogenic (Kim Oanh et al., 2002). Furthermore, studies have found respiratory infection, with pneumonia and bronchiolitis as common ailments (Sharma, et al., 1998), attributable to the use of kerosene in households, particularly amongst women and young children (Behera et al., 1998). Replacing kerosene lamps with electricity has also been shown to reduce accidental poisoning (Abu-Ekteish, 2002, Kaufman et al. 2000) and burns (Mabrouk et al., 2002). However, the widespread expansion of grid electricity is deemed a financially unviable alternative to rural households and has been a challenge to implement since the 1970s (Wamukonya, 2007).

Therefore, decentralized, or off-grid energy, solar systems are an attractive alternative option for Africa owing to the abundance of available solar resources (i.e. high solar radiation) and the remote, hard-to-reach, characteristic of rural populations. Solar systems are also impervious to supply or price uncertainty and eligible for support from institutions that advocate low-carbon energy development (Deichmann et al.). Furthermore, the benefits of the adoption of solar systems has been identified in literature as providing a high quality light source that can extend working hours, deliver improved health services and enable income generating activities (Gustavsson, 2007). There are also other opportunities with safe and better quality access to light such as improved conditions for studying in the evenings, rural development and community safety. In this study, we approach the SPL market from the perspective of education, a perspective not frequently addressed in literature. While education is often cited as a co-benefit to the introduction of off-grid solar lighting, only a few studies provide empirical data to back these claims (Gustavsson, 2004).

For these reasons, non-governmental organizations, multilateral institutions, local governments and private sector entrepreneurs have sought to catalyze the off-grid lighting market to reach energy access targets (Wamukonya, 2000).

Of recent interest to the off-grid lighting community is the development of affordable, quality “pico-PV” products, such as solar lanterns (GTZ, 2010). Technology development in PV manufacturing and battery development has allowed for a new breed of off-grid lighting products, which may be sold in the price range of $10-100, rather than $100-1000. Historical experiences driven by development cooperation have promoted the use of pico-PV products as well as larger Solar Home Systems (SHS) throughout developing countries, with mixed experiences. While these products provide access to lighting, charging, and potentially radio/TV, and cell-phone charging abilities, they are also characterized by high upfront costs and maintenance difficulties. Nevertheless, a number of innovative approaches to SHS distribution exist, including the one-handed/dealer credit model popularized by Grameen Shakti in Bangladesh, and the two-handed/end-user credit model popularized by SEEDS in Sri Lanka. These SHS implementation models effectively couple finance and technical expertise to increase the penetration of SHS installations in rural areas (Rolland et al., 2011).

Although a growing number of private sector initiatives have emerged in recent years aiming to commercialize such products for the BOP, with the cost of system components dropping and quality improving, the SHS market continues to face significant barriers and significant growth is doubtful over the next decade (World Bank 2010, GTZ 2010). Main barriers identified often include aspects such as end-user acceptability, consumer finance, enterprise finance, distribution, maintenance, durability, and lack of a conducive regulatory environment. With a thriving BoP landscape, new approaches to innovative business models are emerging that integrate locale specific distribution and sales strategies tailored to local conditions, product development innovations to meet the specific needs for BoP consumers and the sustainability of the business model ensuring scalability and long-term viability (DI, 2007).

1.2 Context Behind Research Placement

This study was performed in the context of the RENEW IS-Academy, a Dutch research collaboration investigating energy access and development cooperation in Eastern Africa (Beukering, 2009). The main project partners include the Institute for Environmental Studies (IVM), the Energy Research Centre of the Netherlands (ECN), and the Dutch Ministry of Foreign Affairs (DGIS). This study is aligned to themes 1 and 2 of the RENEW project, which focus on business opportunities for sustainable energy access, and the household perspective in sustainable energy transitions in BOP communities respectively.

A partnership with Philips Lighting and RENEW was critical to make this study possible. I performed an internship at Philips lighting to align with the 2011 market entry of Philips Lighting products in Rwanda. In Rwanda the study was made possible through a partnership between the National Teacher’s Savings and Credit Cooperative (SACCO), a Rwandan teacher’s financial institution under the cooperative form, and was supported by the Rwandan Ministry of Education.

1.3 Research Aims and Approach

The proposed research question “How do Solar Portable Lighting (SPL) products affect the amount of time spent on educational activities in Rwanda?” examines the impacts

of SPL products on educational activities undertaken by teacher and student households in rural Rwanda. The primary indicators for the research question are;

- Time spent on educational activities with the introduction of the SPL light source as compared to the baseline study
    - Days a week spent on educational activities at home
    - Hours a day spent on educational activities at home
- Social attitudes and values
    - Household attitudes toward education
    - Attendance levels at schools by students
- Resources and physical environment available for households to conduct educational activities
    - Do households have access to educational materials to study with?
- Economic
    - Baseline kerosene and candlelight expenditure
    - Avoided cost of kerosene and candlelight with the introduction of the SPL
    - Willingness to pay and payback period of the SPL

While focusing on the ability of the SPL to increase educational utility, the study will first assess existing lighting practices in households, and also provide insight into the economic impact of the SPL products. As four distinct SPL products are used in the study, a comparative product analysis is also provided.

1.4 Rwanda

This section provides an overview of the socio-economic profile of Rwanda; identifying key country features and a review of its energy sector. For further information, please refer to ANNEX A.

1.4.1 Country Profile and Demographics

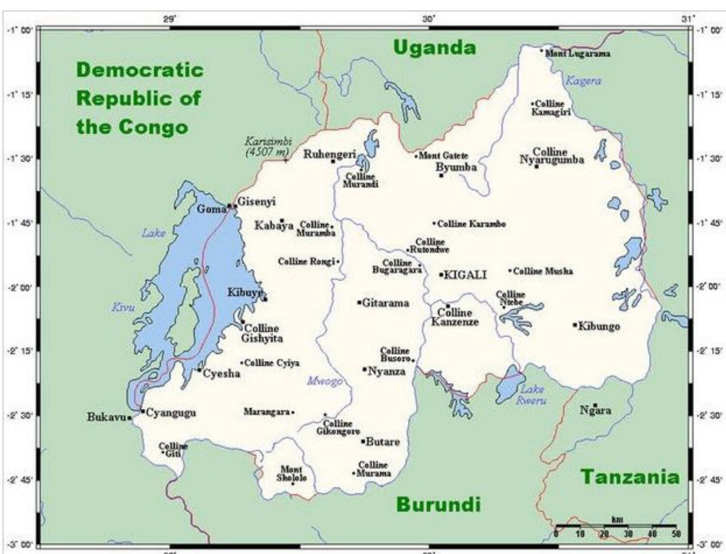

Figure 2: Map of Rwanda. Source: Wikimedia

Rwanda is a small, landlocked nation located in the Great Lakes region covering a mere 26,338km2 and bordered by Tanzania, Uganda, Democratic Republic of the Congo (DRC) and Burundi. Rwanda was devastated by civil war and genocide in the 1990s, followed by border wars that ended in 2002-2003. As a result, domestic population patterns have fluctuated considerably. Currently, it is estimated that the population is 10.5 million with close to 1 million residing in the country's capital, Kigali and approximately 90% of the population residing in rural areas (GoR, 2007). It is also one of the most densely populated countries in the world, and the most densely populated on the continent, with 370 people per square kilometre and the population growing by 2.8% per year (UN, 2008). It is estimated that approximately 80% of the population is engaged in agricultural activities, making up 40% of the GDP (MININFRA, 2009). It is predicted that by 2020, 70% of the population will be in rural grouped settlements and 30% will reside in urban areas. Furthermore, rapid population growth combined with increase in fertility rates and a decline in infant mortality rates places further pressure on an already densely populated environment. (NSIR, 2005)

1.4.2 Macroeconomic Background

Rwanda is a low-income economy with an annual GDP of approximately US $5 billion, which is largely dependent on aid inflows. The GDP/Capita for Rwanda is approximately US$548 for 2010, which is up from US$200 in 2000 (World Bank Development Indicators, 2011). Despite this impressive growth in GDP, 56% of the population lives below the poverty line (UNDP, 2011).

The 1994 genocide not only devastated Rwanda's economy and ability to attract foreign investment but destroyed a large proportion of its human capital; close to one million people died and approximately 3 million became refugees, resulting in a deconstruction of the socio-political system and a dramatic increase in poverty levels (IMF, 2002). The intensive reconstruction phase that followed focused on a poverty reduction strategy for socio-economic development that was supported by bilateral and multilateral agencies. This led to substantial improvements with the 2000-07 years as the turning point for implementing the foundations for progress towards its long term development goals, which are embedded in the Government of Rwanda's (GoR) Vision 2020.

1.4.3 Vision 2020 and MDG Goals

Vision 2020 was formed from a national consultative process that took place in the Urugwiro in 1998-1999 to transform Rwanda from an agricultural economy to a knowledge-based society. Specifically, it's objective was to set a strategic direction for the future of the country through a set of measureable policy goals to achieve political stability, high levels of growth and poverty reduction through various measures; redesign governance structures through fiscal decentralization and reform, modernize agriculture, promote environment and natural resource management, develop entrepreneurship activities and expand the private sector with focus on service industries (GoR, 2000)[1].

1 In addition, the Poverty Reduction Strategy Paper in 2002 formed the basis for Government and donor interventions ever since. The Economic Development and Poverty Reduction Strategy 2008-2012 (EDPRS) is a complimentary policy document that provides a framework for the implementation of Vision 2020 in the medium term to guide and mobilize resources from the GoR, donors, civil society and the private sector.

1.5 Review of Energy in Rwanda

Energy is a key strategic sector for poverty reduction as it fosters socio-economic development and is believed to contribute to the achievement of the Millennium Development Goals (MDGs). Furthermore, the GoR recognizes that to promote economic development, it must increase access to energy in rural areas. With rural electrification rates at a mere 1.3% in Rwanda (compared to 11% average in rural Sub-Saharan Africa), the focus of the government's energy policy is to promote activities that will increase access to electricity and provide a low-cost high quality service whilst supporting a financially viable value chain for private suppliers of energy (UNDP/WHO, 2009).

Rwanda's renewable energy policy priorities were initially guided by the Rwandan Government's Vision 2020, which has set a substantial target of increasing access to electricity for the population from 6% (of 2000 levels) to an ambitious 16% by 2012 and 35% by 2020, particularly drawing attention to the development and utilization of renewable energy resources and technologies (GoR, 2000, 2007). The more recent EDPRS and Energy Policy and Strategy documents argue that the optimal utilization of renewable energy sources and technologies will alleviate the current supply gap and minimize dependency on expensive fuel imports.

1.5.1 Primary Energy Trends and Policy

The hilly and landlocked character of Rwanda makes the provision of energy to rural areas difficult and expensive. The use of traditional fuels, such as biomass in the form of woodfuel, is prevalent and has accelerated due to population growth and industrial expansion with households as primary drivers. Therefore, predictably, Rwanda's energy consumption is for the most part in the form of traditional biomass making up 86% of the country's primary energy source with the majority used directly as wood fuel (57%) followed by charcoal (23%) and crop residue and peat (6%). The remaining primary energy balance, electricity, accounts for 3% and petroleum, which is primarily used for transport, accounts for 11%.

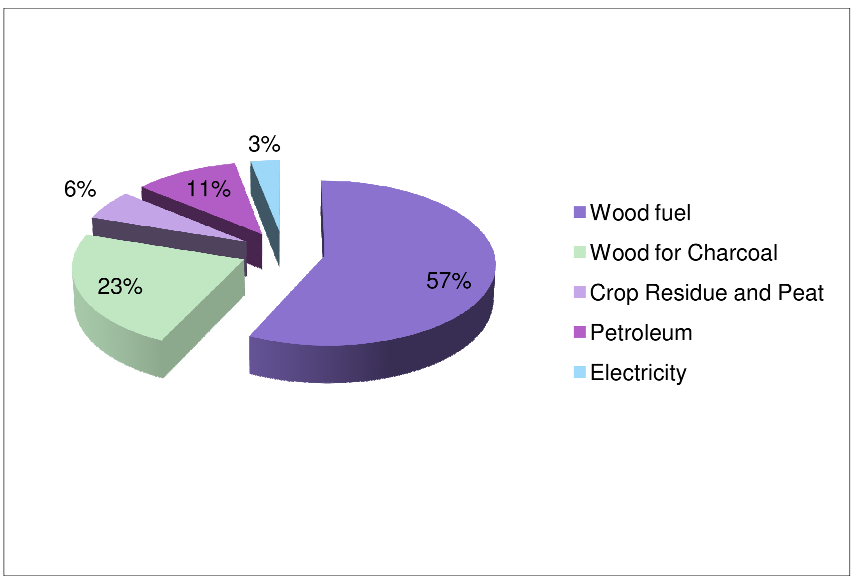

Figure 3: Primary Energy Balance. Source: MINIFRA, 2009

Currently, Rwanda has 95MW of installed capacity most of which is dominated by hydropower plants. The electricity supply consists primarily of outdated hydroelectric and diesel power stations (MINIFRA, 2010). Of these approximately 50% come from

hydropower and 45% from oil-fueled power (King, 2011). This makes the country susceptible to climatic and environmental fluctuations such as rainfall patterns. A significant proportion of Rwanda's energy comes from imports from neighbouring countries. Fossil fuels account for 95% of energy imports, making Rwanda susceptible to oil price shocks.

Households contribute the largest share of primary energy consumption (MININFRA, 2009) yet primary energy consumption in Rwanda is very low (UNDP/WHO, 2009)[2]. Despite this low consumption, energy spending accounts for approximately 14% of non-food expenditure and it is believed that this proportion is even higher in poorer households (GoR, 2007).

The GoR has set ambitious energy targets, that can be summed up in *Table 3*, yet the latest figures from recent reports are far from promising (as observed under the second column in *Table 3*) and the approaching 2012 target year will provide a crucial indication of Rwanda's energy outlook in years to come.

Indicator	**Current Status**	**2012 Target**	**2017 Target**	**2020 Target**
Electricity Capacity	84.71MW	130MW	1000MW	1300MW
Electricity Access (% of households with electricity)	10.50%	16%	50%	60%
Electricity Connections	175,000	475,000	1,200,000	
Percentage of energy consumed by households	38	64	75	83
Biomass Energy	86%		65%	50%

Table 3: Key Targets for the Energy Sector by the GoR. Sources: GoR 2000 MINECOFIN 2007, Mininfra 2009, 2010

1.5.2 Renewable Energy

The Rwandan Government has repeatedly expressed the need to increase production of energy from existing sources and for diversification into alternative energy sources such as hydropower, Lake Kivu Methane, solar thermal, solar photovoltaic, wind, geothermal and peat. Rwanda aims to diversify local electricity generation sources and to focus on more cost-effective, robust and sustainable energy sources such as methane, gas, hydro (including micro hydro), solar, wind, geothermal (King, 2011).

The ever increasing demand-supply gap, the lack of local capacity and electricity transmission infrastructure, and the high cost of imported petroleum advocates the use of renewable energy for meeting basic energy and lighting needs of rural communities. However, the prime drivers have been donor projects with efforts remaining scattered and largely outside of the national energy planning process. The level of local capacity in the area of renewable energy also remains low both in the public as well as private sector.

[2] Primary energy consumption is at a mere .17toe (tones of oil equivalent) per capita compared to an average 0.6toe for SSA and 4.7toe for industrialized nations (MININFRA, 2009). In addition , only 10% of the population has access to electricity, with 25% of urban households connected to electricity whilst a mere1.3% have access to electricity in rural areas.

2 Literature Review

2.1 Traditional sources of light and poverty alleviation

The provision of modern, sustainable and reliable energy services is fundamental to addressing many of current global development challenges and the Millennium Development Goals (MDGs) including; poverty reduction, climate change, health and education. It is estimated that one-third of the world's population lacks access to modern energy services. At the current trajectory, there will be more people without access to modern energy services in 2030 than at present (IEA, 2009).

Sub-Saharan Africa has one of the largest off-grid populations; approximately 590 million people have no connection to electricity (IEA, 2009) with 74% of people without access to electricity and about 83% to modern fuels (UNDP/WHO, 2009).

To meet lighting needs, rural households in SSA often use products such as candles and kerosene-fuelled lanterns. Kerosene fuel is expensive, provides low quality illumination and exacerbates health risks compared to modern energy alternatives for lighting. Studies estimate that the cost of kerosene is 3000 times higher than that of compact fluorescent light (cost per lumen-hour of light) (Mills, 2000, UN-Energy, 2005). In addition, households are estimated to spend about 10-30% of their disposable income on fuel expenditures for lighting (World Bank, 2009b).

2.2 Off-grid lighting

In response to the health, cost and safety concerns of traditional energy sources, modern energy, defined for the purposes of this paper as renewable technologies focusing on off-grid solar[3], provides a safer, environmentally benign and cost-effective solution for household fuel consumption in developing nations. The justification for off-grid lighting solutions for rural areas is that it is linked to general strategic development goals including improved health conditions, environmental benefits as well as access to a modern light source and ability to save income.

There are a number of studies that quantify the impact of off-grid solar lighting on the welfare of households i.e. by calculating the avoided cost of kerosene. One study in Malawi that used a market-based approach in rural areas, reported lighting use to increase by 63% with the introduction of solar lights. Furthermore, the study highlighted the high unit cost of kerosene, which averaged at $2.61 per month, accounts for 19.7% of monthly household income (Adkins et al. 2010).

In general, the types of fuel used become cleaner and more efficient and expensive as people move up the energy ladder, as households' socio-economic condition improves (Buekering et al., 2009)[4]. For this reason, the aggregate purchasing power of this low-income segment of the world's population, also known as the "Bottom of the Pyramid" (BoP), deserves attention. It is estimated that the 4 billion people at the BoP make up a $5 trillion global consumer market (Hammond et. Al, 2007). The business interest in

[3] Modern energy is typically described as new technologies, such as electricity services or renewable energy, that diverges from traditional energy sources such as biomass (Hammond, 2010)

[4] The paper presents an "energy ladder" that indicates energy sources for different activities at different income levels. For lighting, the ladder indicates that low-income households use candles or batteries to meet their lighting needs. As income increases, households switch to kerosene and, finally, to electricity.

the BoP markets is rising within consumer good markets, i.e. cell phones, and developing robustly. Comparatively, the technology transfer in the provision of modern energy services for the BoP continues to face major challenges. BoP consumers have little or no access to credit and are unable to finance the high upfront costs of solar systems. Furthermore, private sector involvement remains fragmented and modest in this largely donor driven market, partly owing to implementation challenges across the value chain (World Bank, 2010). For this reason, the energy supply market for the BoP in SSA remains outside the reach of private sector initiatives despite the evolution of financial and business models catered to the BoP (Prahalad and Hart 2002).

2.3 Off-grid lighting and private sector potential in Rwanda

Solar energy is a particularly attractive option for Rwanda as the potential for solar electricity generation is virtually limitless. Much of the country experiences high levels of solar radiation, a daily average of between 4.8-5.5 kW h/m2, approximately five times more than London (Safari et al., 2009).

Although there are currently no comprehensive projects that address to building of a private Photovoltaic (PV) market, the 'Rwanda: Sustainable Energy Development Project' (SEDP) by the Global Environment Fund (GEF) draws some attention to the current weak position of the private sector by establishing 3 core measures for solar energy development(World Bank, 2009);

1> Developing national standards for institutional PV applications
2> Building capacity and conducive frameworks to allow local private firms to participate in international tendering for the Rwandan market
3> Developing a commercial SHS market for rural areas.

Rwanda faces considerable challenges to building a PV off-grid solar market; as a landlocked country, Rwanda faces some of the highest transport, energy and communication costs in the East Africa region. Transport costs, as a share of import prices, are nearly three times higher in Rwanda than in neighbouring Tanzania or Kenya – highlighting a major disincentive to importing goods and the need to reduce business costs as a priority in the medium term policy objectives of the nation (World Bank, 2011). Vision 2020 sees Rwanda as a middle-income economy of approximately US$900 per capita and a regional business hub by 2020. For this reason, the Government of Rwanda (GoR) is committed to facilitating a strong private sector. Major barriers to economic transformation and private investment are identified as low human capital and skills, governance constraints, lack of entrepreneurship, low domestic saving rates and insufficient access to finance (GoR, 2007). In 2003, Rwanda took various measures to emulate East Asian business regulation reforms (i.e. Singapore) and, as a result, 22 business regulation reforms have been implemented since 2005. Currently, reforms in "doing business" have led Rwanda to emerge, for two successive years, as a top global reformer in the "ease of doing business" (World Bank, 2011). This remarkable progress underlines Rwanda's objective to catalyze private sector-led development by making changes to the regulatory framework.

The GoR recognizes that off-grid solar is a viable solution for the development of rural areas as it provides a relatively inexpensive way of giving households at least minimal electricity access (MININFRA, 2009). At the same time, the GoR is enabling a commercial off-grid lighting market through the exemption of solar equipment from import duty; and as of 2010, energy supplies including energy saving lamps, such as Light-emitting diodes (LEDs), are exempt from Value-Added-Tax (VAT) to encourage the conservation of energy and promote the use of clean technology (Rwanda Revenue Authority, 2011).

2.4 Educational impacts of Solar Portable Lights

There is effectively no sub-Saharan specific study that focuses on the impact of off-grid lighting on time spent on educational activities for teacher and student households, with the exception of a study in Zambia. This study reports an increase in the time spent by students on reading and studying activities as well as emphasizing the high light quality of the Solar Home System (SHS) compared to traditional light sources. Furthermore, as the Solar Home System was able to provide access to television, the study found that this improved awareness of the situation in the country and foreign language skills of households (Gustavsson, 2007). However, an earlier study presents unclear results, indicating that time spent on reading and writing by students increased whereas time spent on studies actually decreased (Nieuwenhout et al., 1999). Other studies mention that access to light improves educational activity after dark as a co-benefit (Willkins, 2002, Adkins et al. 2001), but these studies do not provide empirical evidence to substantiate these claims (Gustavsson, 2004).

There also exist several non-SSA studies that provide empirical evidence on the impact of off-grid solar lighting on education; one such study in India identified that the introduction of solar lanterns increase educational activity in student households from 1.5 hours to 2.7 hours per evening (Agoramoorthy et. al, 2009). In spite of the assumed benefit of improved lighting on educational activities, and its subsequent impact on the development of rural communities, the subject is largely unexplored.

3 Methods

3.1 Introduction

The aim of this study is to carry out a field pilot of four Philips Lighting products in rural households in Rwanda. The specific focus is to examine whether the lighting products may provide educational benefit to a target group comprising rural teacher and student households. The study is one component of a larger market study for Philips off-grid lighting products in East Africa.

Desk based literature review was performed throughout planning, data analysis and data collection phases. Planning activities were undertaken in consultation with Philips Lighting in Eindhoven, the Netherlands, and RENEW project members at IVM and ECN.

The fieldwork component of this study includes the collection of baseline data from households in the survey, the distribution of Philips Lighting products to households participating in the field pilot, and the subsequent data collection from participating households six weeks later.

3.2 Philips Case Study

In 2008 Philips, in partnership with the Dutch Government, initiated the 'Sustainable Energy Solutions for Africa' (SESA) project to see the development of sustainable and affordable solar-powered product in sub-Saharan Africa. The project intends to provide 10 million people with off-grid lighting products in ten SSA countries by 2015. By 2011, Philips' portfolio included a number of products including the Uday Mini, the Solar LED torch, the Solar Home System and the Solar Reading Light.

3.2.1 Product Specification

The four products utilized in this study offer diverse capabilities and range from an Freight on Board (FOB)[5] price.

	The Solar Home System is a complete LED home lighting kit and provides two lights with suspendable cables that can be installed in two rooms. Furthermore, the Solar Home System provides a mobile charger.
	The reading light is a lightweight LED SPL with a built-in rechargeable battery used with a 0.4W solar panel. It was developed with the specific intention to serve reading and writing needs at dark.
	The Solar Torch is a compact LED torch that can be charged with solar energy or with a manual crank[6]. There are two light levels and this product also provides mobile phone charging capabilities.
	The Uday Mini is an older version solar lantern that uses a PLS lamp.

Product	FOB Price	Usage	Solar Charge	Battery	Charging time of battery	Lamp	Lamp lifetime	Cell phone charging capability
Solar Home System	$48	10 hours with one light unit, 5 hours with both units	3W polycrystalline silicon solar panel	4V 4ah battery	8 hours	Each unit contains 10 LED light points	10,000 hours/10 years	YES
Reading Light	$11	5 hours	0.4W crystalline silicon solar panel, IP44	2 * 1.2V NiMh AAA battery, 750 mAH	8 hours	2 long life LEDs	10,000 hours/10 years	NO
Solar Torch	$9.5	4 hours	Solar energy or manual crank		8 hours or by cranking	LED	10,000 hours/10 years	YES
Uday Mini	$41	4-5 hours	5W polycrystalline silicon solar panel	6V 4.5Ah SLA battery	6-10 hours	5w PLS 4 pin lamp	8,000 hours/ 8 years	NO

Table 2: Philips renewable energy lighting range specifications

5 Freight on Board (or Free on Board) indicates that the seller, Philips Lighting B.V, pays for the transportation of the goods to the port of shipment including loading cost (in this case to Dar Es Salaam or Mombasa). The buyer, or distributer, pays the costs and bears the risk of loss and damage from that point. Therefore, the FOB price is the price the distributor must pay for the shipment. (Intercoms FOB, 2000)

6 One minute of cranking provides 30 minutes of light with the 1 LED on. 2 minutes of cranking provides 1-minute talk time and 15 minutes of cranking provides 10 minutes talk time.

3.3 Field pilot locations

There exist five administrative provinces, 30 districts and 416 sectors in Rwanda. This study focused on data collected from three administrative districts: Rulindo (Northern Province), Kamonyi (Southern Province), and Kirehe (Eastern Province). These location choices were made in consultation with Philips Lighting, the Ministry of Education in Rwanda, and the Teacher's SACCO who was the main field implementation partner.

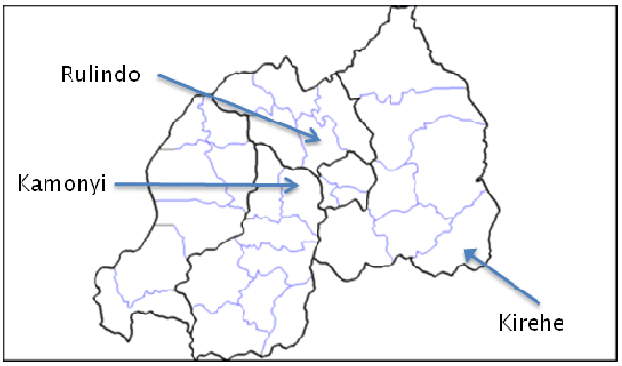

Figure 1: Map of sectors where fieldwork was conducted. Adapted from Wikipedia

3.4 Data collection

Results from two household surveys form the data set. Data collection activities occurred prior to the distribution of products and six weeks after product distribution. The first survey assessed the baseline situation of lighting in households, prior distribution of the products. The second survey, applied a month and half after the baseline survey, assessed the subsequent impacts of the allocated products.

3.4.1 Product distribution

The number of products distributed amounts to a total sample size of 66 products (*Table 1*). The aim was to distribute a total of 72 products (18 of each) equally among the three administrative sectors. Due to field difficulties, there were 22 products distributed to Rulindo, 21 to Kirehe, 23 to Kamonyi.

Product	**Quantity**
Solar Home System	18
Reading Light	18
Solar Torch	15
Uday Mini	15
Total	**66**

Table 1: Quantity of distributed products

In each sector, 6 student households and 12 teacher households participated. Student households are defined as pupils in the participating districts and teacher households are defined as teachers that are members of the Teacher's SACCO. Headmasters of participating schools selected the student households. The key informants of the study are teacher and student households that are users of kerosene fuel or candlelight for lighting. Interviewed households had no access to electricity.

3.4.2 Survey design

In designing the two surveys, three aspects were accounted for. First, baseline data was required for an ex-post evaluation of impacts on time spent on education after the distribution of the solar lights. Secondly, to assess the use of the solar product as compared to the baseline light source. Thirdly, to assess the economic and social impacts associated with the solar products.

The baseline survey is composed of the three following sections. The survey can be viewed in Annex B.

- **Household roster and education:** This section illustrates the household and identifies lighting needs in the household. It identifies the number of people in the household, their sex, their relationship to the head of the household, the income-generating activities performed by members of the household, and how many members are currently enrolled in school. Furthermore, the number of rooms per household is also identified.

- **Current lighting practices:** This section identifies the amount of kerosene and candlelight purchased by the households and their economic burden. The average hours of use per night is indicated, followed by an analysis of the precise uses of light per evening.

- **Education:** This section is divided into two sections; student households and teacher households. Students describe their schooling, access to educational resources such as schoolbooks and how many hours they study per evening. Teacher households provide information on how much time they spend conducting educational activities such as grading work and preparing classes.

The second survey (Annex C) is organized identically to the first survey with an additional section to describe product functionality.

Furthermore, in order to measure willingness-to-pay, participants were asked how much they were willing to pay until the product stopped working. They were also asked their preferred payment schedule (i.e. daily, weekly, monthly). In order to calculate the payback period, a conservative approach of the price of the product was assumed, which included battery and light replacements over the life of the product.

3.5 Data analysis

The approach is a descriptive analysis of the survey data. In addition, qualitative observations were collected from the group discussions. The data analysis is divided into three areas: Aggregate analysis, Product analysis, and Product comparison.

The aggregate analysis provides a snapshot of current lighting practices and the overall impact of SPL on these practices for teacher and student households participating in the pilot.   The product analysis analyzes product specific outcomes

relating to the research question. The product comparison assesses product performance in terms of functionality, use of light, impact on education as well as economic impacts.

3.6 Limitations to the study

The major limitation to the study is that a statistical analysis was not employed for the data analysis. There were some wide fluctuations in the baseline data, particularly in regards to the average amount spent on kerosene and candlelight per product sample. Furthermore, a small deduction in time spent on educational activities can be observed aggregately for teacher households, and also at a product level of analysis for some products; such observations would benefit from a statistical analysis to test their significance.

A further limitation of the study is that there were seven absences in the follow-up survey, making up a total of 59 participants out of 66. The impact of this shortfall may be assessed through a statistical analysis of the data.

The survey also lacked a control to identify whether the light was used in a communal space where educational activities could take place simultaneously with other activities. However, the use of light per evening was posed as a separate question to the time the SPL was spent on various activities per evening.

The Willingness-to-pay (WTP) was based on a straightforward question posed to survey participants based how much they would pay until the product stops working (with their preferred payment term i.e. monthly). However, there is a wide range of literature that explores various techniques in measuring the WTP, which was not explored due to time limitations and the wide-ranging scope of the study.

4 Results

Fieldwork results are presented in this chapter in three sections. The first section contains baseline survey data collected prior to the start of the product pilot. The second and third sections of the chapter contain SPL survey data collected six weeks after product distribution.

Baseline survey results are provided in section 4.1. These results describe the existing lighting situation of the households. Data related to existing lighting practices, lighting expenditures, and the use of lighting for educational activities are included.

In section 4.2, aggregate changes to the baseline lighting situation are described. These results include all households participating in the SPL pilot.

4.3 presents product analyses at comparative levels.

Annex A presents product analyses at individual levels

4.1 Baseline survey results: Overview of existing lighting situation

4.1.1 Background information

Table 4 outlines that of the average 6.74 persons per household with approximately 3 members currently attending school. Households also have approximately 7 rooms per households.

Product	No of people in living household	Number of members attending school	Number of rooms in the home
Solar Home System	6	3.17	7.11
Reading Light	7.56	3.83	7.07
Solar Torch	7.06	3.13	6.85
Uday Min	6.33	3.33	5.58
Average	6.74	3.38	6.69

Table 4: Background information on households

Data collected from households, as seen in *Table 5*, indicate that there is a strong emphasis on education. In a focus group held with teachers and parents there was also consensus that this emphasis had grown with the government’s removal of tuition fees under the 2020 Vision ‘Nine Year Basic Education’ programme. Students who were interviewed indicated that they attended school 5 days a week on average. All of the students indicated that they had reading and exercise books and 76% had access to a library at their school and 87% had access to other reading materials at home. These social attitudes and values to education further support the need for household light for educational purposes.

Product	Travel Burden to school (hours by foot)	Do you have an exercise book (% answering yes)	Do you have a reading book (% answering yes)	Does your school have a library with reading books? (% answering yes)
Solar Home System	1 hour 11 minutes	100	100	83.33
Reading Light	1 hour 4 minutes	100	100	60
Solar Torch	49 minutes	100	100	60
Uday Mini	40 minutes	100	100	100
Average	1 hour	100%	100%	76%

Table 5: Educational resources available to students and travel burden to school

It is also important to note that it is dark by the time most teachers and students get home. All participants in this sample travel to school by foot and the average journey time is 1.18 hours. Teaching hours are from 7.20am – 5pm and student hours are either the full day or a half-day from 7.20am – 2pm. Since it gets dark in Rwanda by 6pm on average, all teachers and the majority of the students get home after dark. None of the interviewees had electricity access in their schools.

4.1.2 Education and existing lighting sources

Existing lighting practices confirm that kerosene or candlelight is primarily used for educational activities (as observed in *Figure 4*). Teacher and student households together spend approximately 2 hours and 20 minutes on educational activities per evening followed closely by cooking (1 hour 50 minutes). Data also indicates students study on average 5.29 nights a week and 2 hours an evening with the existing light source.

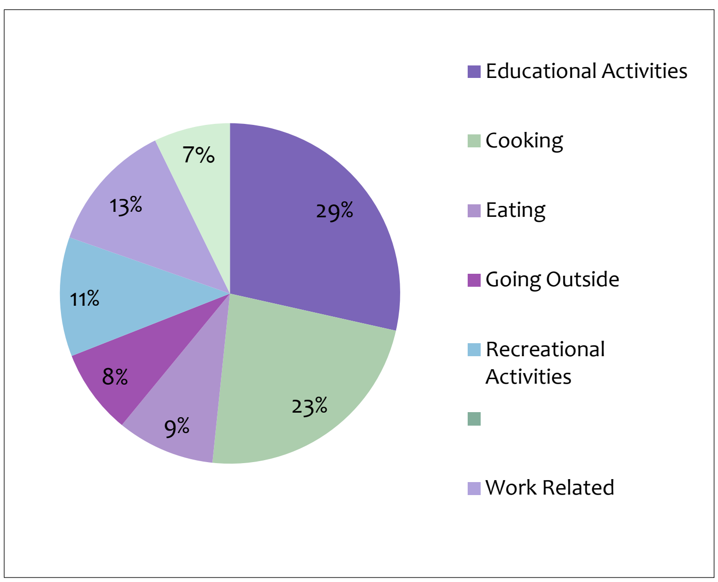

Figure 4: Household use of kerosene and candlelight per evening

The correspondence between relatively high household spending for existing light sources and the primary use of light used for educational activities reveals the value of education for households and insinuates their willingness to pay in this respect.

1.1.3 Lighting expenditure and existing lighting sources

In the aggregate sample, 41% of the households purchased candles and 71% purchased kerosene. *Figure 5* illustrates the average amount spent on kerosene and candles for all households which amounted to over 6268RWF (approximately $10) and all households spending an average of 4200 RWF (approximately $7). With a litre of kerosene costing a hefty 1089 RWF and a candle costing 60RWF on average, households indicated that they spend roughly 17% of their total income on light. In addition, the purchase and financial burden of the kerosene and candlelight is considerable at approximately 3.9 km (or 2 hours 20 minutes a week).

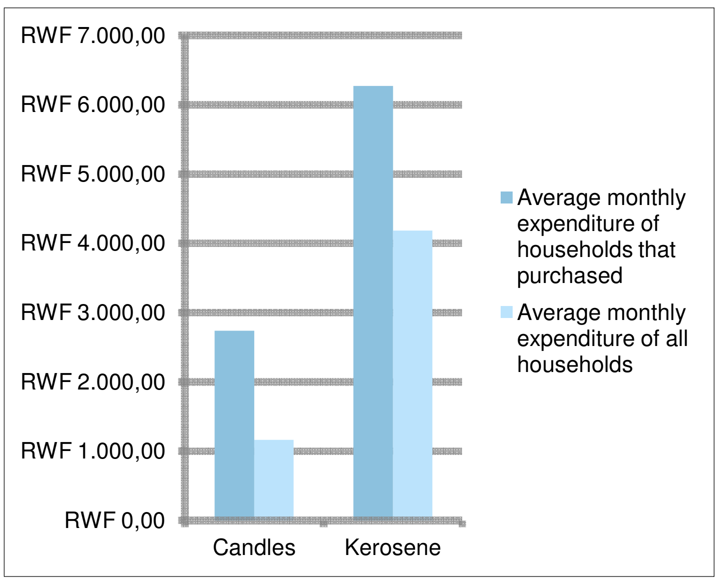

Figure 5: Baseline lighting expenditure for candlelight and kerosene

4.2 SPL survey results: Changes to existing lighting situation

In this section, changes to the existing lighting situation are presented, using aggregate data from all households participating in the pilot.

4.2.1 Education and SPL lighting sources

As indicated by *Figure 6*, the SPL products were predominantly used for educational activities with the rest of the activities were fairly equally distributed. For the SPL's that provided cell phone charging abilities, particularly the Solar Home System, this also made up a considerable portion of the use of the light. The SPL was used for 130 minutes for educational activities per evening for, making up 44% of the total use of the light.

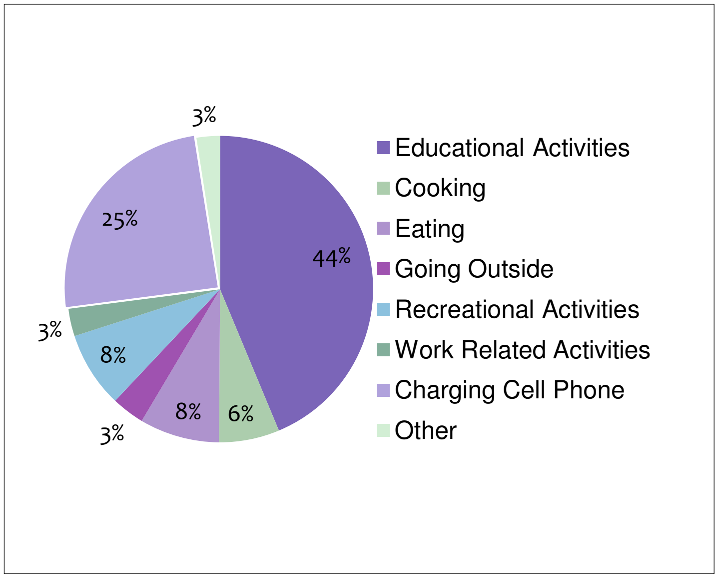

Figure 6: Household use of SPL product per evening

However, *Figure 7* shows that there was an aggregate decrease in the time spent on educational activities by all households by 10 minutes.

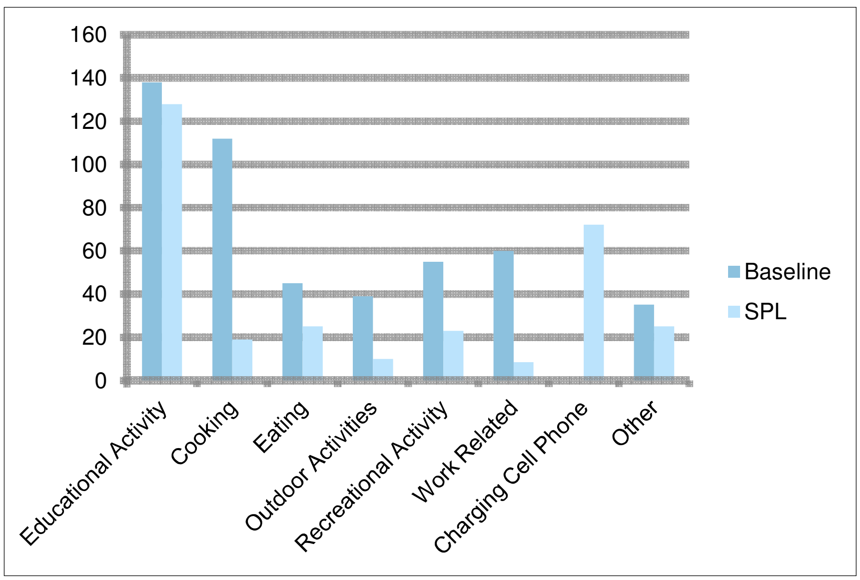

Figure 7: Comparison of time spent on activities with light (minutes per evening)

Table 6 presents the use of the SPL; the products were used on average 3.5 hours a day, compared 4.47 hours of kerosene and candlelight use in the baseline situation, which highlights that they provided less overall light capacity than the previous sources of light. Many participants declared that the lights did not last long enough. This is also reinforced by the fact that households did not stop purchasing kerosene and candlelight after the SPL was introduced to the household.

Product	Baseline: Hours spent per evening using lighting*	Baseline: Days used per week**	Baseline: Hours used per week	SPL: Hours used per evening	SPL: Days used per week	SPL: Hours used per week
Average of all products	4.47	6.67	29.75	3.25	6.60	21.48

Table 6: Hours of light used per evening
**Aggregate use of kerosene and candlelight averaging for all households **Average days used per week by households that purchased*

It is also important to consider that households, with a lot of occupants and number of rooms, need additional light for other activities. The fact that 44% of the use of the SPL was used for educational activity is substantial, compared to the baseline situation where 29% of the duration of the light was used for educational activities per evening; implying the SPL is better suited for reading and writing activities.

The SPL products had a noteworthy impact on time spent on educational activities by students as seen in *Table 7*. With the introduction of the SPL, students revised on average 6.21 days a week used the products 2 hours and 20 minutes per night on average. The hours spent on educational activity increased by 4 hours per week with the introduction of the SPL product.

	Baseline: How many days a week do you use light for educational activities?	Baseline: How many hours a night do you use light for educationa l activities	Baseline: Hours used per week for education al activities	SPL: How many days a week do you use the light for educationa l activities?	SPL: How many hours a night do you use the light for education al activities	SPL: Hours used per week for education al activities
Total Avera ge	5.29	2.00	10.60	6.21	2.33	14.72

Table 7: Comparative use of light for educational activities by students

On the other hand, the amounts of time teachers spend on educational activities decreased by 10 minutes on average.

4.2.2 Lighting expenditure and SPL lighting sources

Overall data indicates that the expenditure on kerosene and candlelight decreased. Percentage of household that purchase kerosene also fell, however, the percentage of households purchasing candlelight went up.

Figure 8 illustrates the dramatic decrease in the average amount spent on kerosene and candlelight (of all households) after the introduction of the SPL.

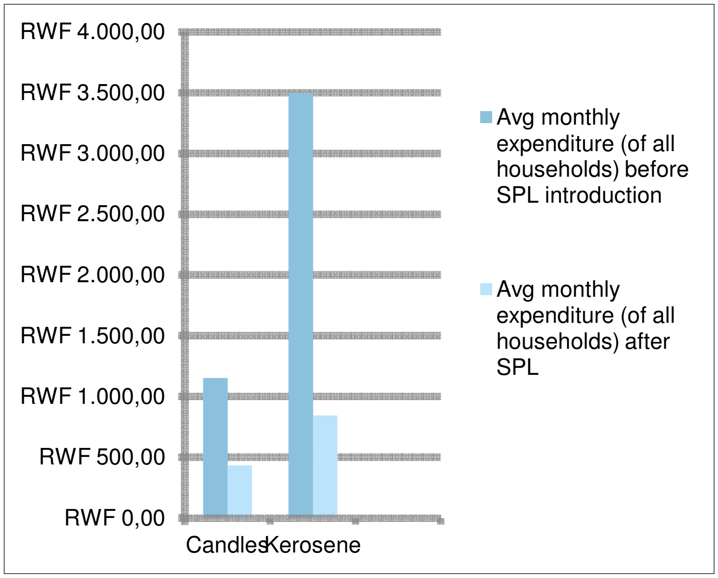

Figure 8: Comparative average monthly expenditure by households for kerosene and candlelight

Furthermore, compared to the baseline, the number of households purchasing candles increased by 27% and the number of households that purchased kerosene decreased by 27%. The total increase for the amount of candles purchased can be accounted for by the fact that candlelight was substituted for kerosene as a supplementary, cheaper, light source in addition to the SPL. On closer inspection, these additional lighting requirements can be accounted by the high number of people and rooms per household.

4.3 Comparative Analysis

4.3.1 Use of SPL and functionality

The hours spent per night for products varied slightly. *Figure 21* shows hours spent per day by household for each product.

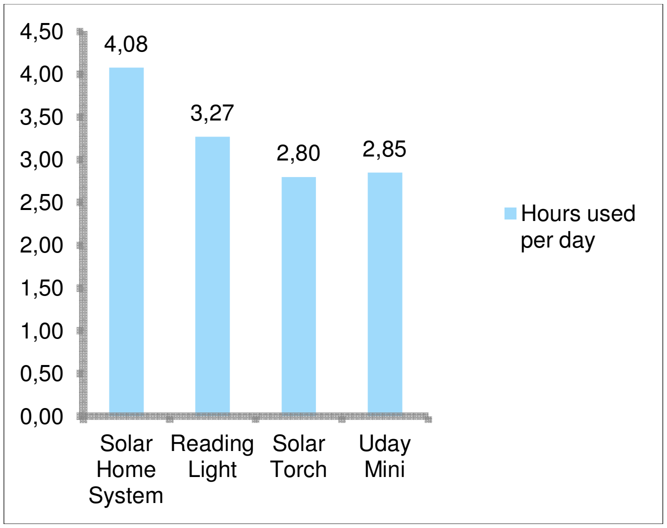

Figure 21: Comparative average monthly expenditure by households for kerosene and candlelight for the Uday Mini

The Solar Home System was used for the longest amount of time per evening. The Reading Light was used only about 40 minutes less per evening despite its 5 hour battery life. On the other hand, the Solar Torch and Uday Mini fell slightly below 3 hours of use per day. This suggests that families did not fully charge the batteries or that the lights did not working effectively.

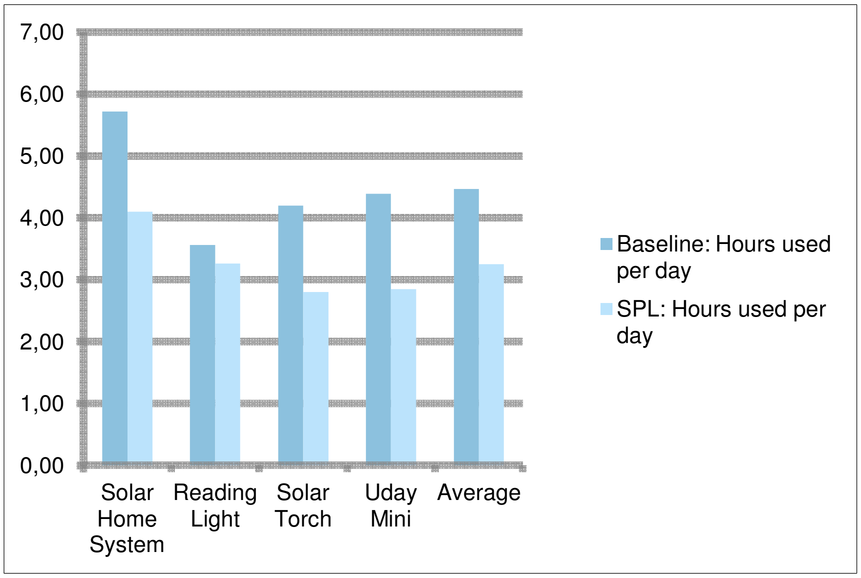

Figure 22: Hours of light used per evening in the baseline situation compared to the SPL

Furthermore the fact that the Solar Home System and Solar torch were not used to their full lighting potential- 5 and 4 hours of light respectively -may be accounted for by the fact that households used these two products for charging cell phones.

Another factor that may have affected light usage by households was functionality of products. Two of the Solar Home Systems stopped working during the duration of the survey, one reading light did not work initially and one stopped working during the survey period. Two Uday Mini's did not work; however one was repaired and another seemed to have been damaged by the user. Three of the Solar Torch's stopped working during the period; at least one of these appeared to have been damaged by a user. These instances of product failure are shown in *Table 8*.

	Solar Home System	Reading Light	Solar Torch	Uday Mini
Total number distributed	18	18	15	15
Light stopped working	2	1	0	2
Battery stopped working	2	2	3	1
Solar Panel Broke	0	1	0	0
Failure of wiring	0	0	1	0
Installation difficulty	1	1	0	0
Not Bright Enough	0	8	8	1
Doesn't Last long enough	2	5	6	5

Table 8: Functionality of products

4.3.2 Highlights of user feedback

The Solar Torch, which had the lowest usage per night, generated the largest amount of negative feedback from users. The major shortcoming cited was inadequate light quality and duration of lighting service. It was also disliked for its its failure to charge cell phones and the general nuisance of the manual crank for phone charging.

On the other hand, the Solar Home System, which had the highest usage per night, received the least complaints. The product was described as extremely valuable to the participating households, particularly as they were able to conduct multiple activities in a communal space. Similarly, the Uday Mini was well received and the brightness of the light produced was considered a strong product feature.

4.3.3 Impact on Education

All the products were primarily used for educational activities. The use of SPL lights was rather evenly distributed among other activities. Due to its unique battery charging abilities, the Solar Home System was used approximately up to 2 hours per evening for charging of cell phones. Notwithstanding, the lack of utilization of the SPL lights for other activities, other than cell phone charging, highlights that the SPL's primary function is for educational activities. It is possible that the other activities were used simultaneously for various activities, although the survey specifically asked how many hours per evening they spent using the light on the activities presented in *Figure 23*.

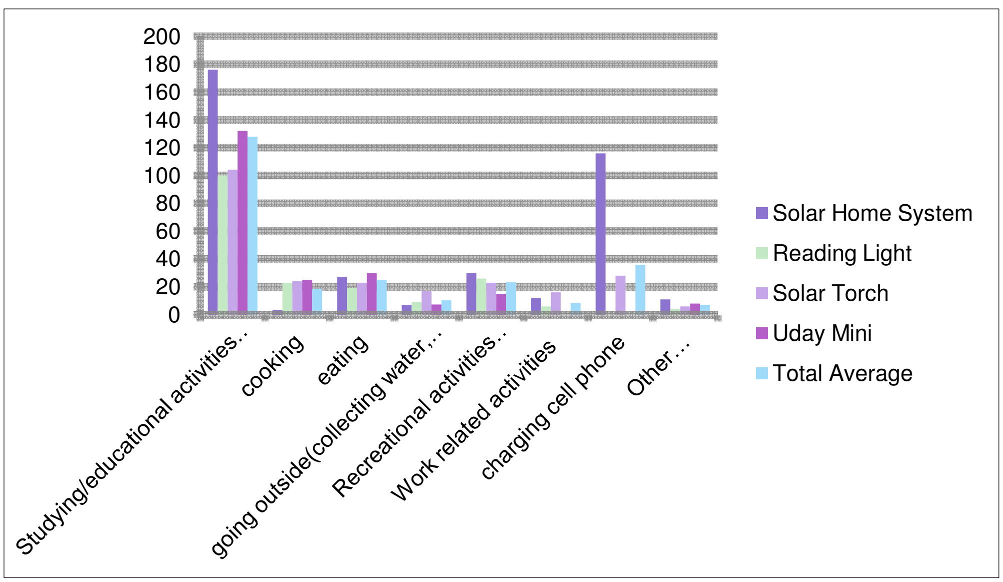

Figure 23: Product comparison of time spent on activities with light

Furthermore, there was a notable divergence in the hours studied per night for students as compared to baseline data.

Table 9 highlights a substantial increase in the hours studied per night for students compared to their previous light source (up to 58%) for both the Solar Home System and Solar Torch. In contrast, the Reading Light actually saw an overall decrease and the hours spent studying for student households who used the Uday Mini did not change.

SPL	Amount of time spent on educational activities with SPL (per evening)	Percentage change in hours studied at night compared to baseline (for students)	Minutes increase/decrease in amount of time spent on educational activities at night compared to baseline(for teachers)
Solar Home System	2 hours 56 minutes	58.33%	33 minutes
Reading Light	1 hour 40 minutes	-6.67%	42 minutes
Solar Torch	1 hour 44 minutes	50.00%	37 minutes
Uday Mini	2 hours 12 minutes	0.00%	0 minutes

Table 9: Product comparison of time spent on educational activities

In regards to the teacher households, the Solar Home System was the only product that increased the minutes spent on educational activities per night. The implication of these varied results will be discussed in the following chapter.

4.3.4 Economic Impacts

Table 10 highlights the substantial percentage reduction in the amount spent on the baseline light sources after the SPL product was received. The numbers in red indicate that the percentage change is below the average calculated for four products per indicator (row 6).

Product	Percentage change in average amount spent on candles and kerosene from baseline (of households that purchased)	Percentage change in average amount spent on candles and kerosene from baseline (of all households)
Solar Home System	-87%	-77%
Reading Light	-77%	-78%
Uday Mini	-87	-88%
Solar Torch	10	-29%
Average	-60%	-68%

Table 10: Product comparison of percentage change in amount spent on kerosene and candlelight as compared to baseline

The Solar Torch, being the smallest product, observably saw the lowest percentage change in income spent on candle light and kerosene. It is also the only product that has an incongruity in this data set; it saw a 56% percentage increase in the average amount spent on kerosene per month (of households that purchased).

Willingness to pay for products varied across the sample. This appeared to be related to lighting expenditure levels that households were used to prior to using the SPL products. Participants with the Uday Mini and the Solar Home system were willing to pay more for the entire product life of the product. However, participants for the Solar Torch and Uday Mini were willing to pay higher monthly payments. The sample for the Uday Mini had the highest average monthly expenditure on candles and kerosene, which may explain the higher WTP.

The payback periods fell well below the product life for all the products. However, for the data set below (*Table 11*), the payback period is not completely comparable due to variability in baseline expenditure for the product samples.

SPL	Assumed life of product	Average monthly expenditure on candlelight and kerosene per year (averaging all households)	Willingness to pay per month until product stops working	Willingness to pay (full amount for product life)	Payback period FOB price*
Solar Home System	10 years	RWF 2,778	RWF 963	RWF 115,560	1 year 2 months
Reading Light	10 years	RWF 4,590	RWF 897	RWF 107,640	4 months
Solar Torch	2 years	RWF 3,633	RWF 1,248	RWF 29,952	2 months
Uday Mini	10 years	RWF 7,607	RWF 1,126	RWF 135,120	5 months

Table 11: Product comparison of Willingness to Pay and Payback period
**denotes calculated values based on user responses*

5 Discussion and Conclusion

5.1 Supporting Educational Progress in Rwanda: The case for SPL

This study reveals that education is an existing priority for rural Rwandan households. For example, the baseline survey demonstrates a complete 100% school attendance rates for students. This high attendance rate can be accounted to the removal of tuition fees under the 'Nine Year Basic Education' programme, which is a component of the GoR's broader vision of turning Rwanda into a knowledge-based economy (MINEDUC, 2008). This is consistent with current statistics that indicate that net primary enrolment rate increased from 74% to 86% between 2000/01 and 2005/06 – highlighting that Rwanda is on track to achieving universal primary enrolment by 2015 (GoR, 2007)[7]. Furthermore, this study finds that domestic attitudes to education are favourable, with baseline lighting sources utilized primarily for educational activities.

Although all households spent slightly less time on educational activities with SPL products than they had with kerosene and candlelight, 44% of the time spent using SPL products was for educational activities compared to 29% of light used for educational activities in the baseline situation. This increase in the proportion of the light source

7 Key indicators include increased literacy rates and completion rates; currently, adult literacy stands at 65% of the total population aged 15 or older (up from 52% in 2000/01), the completion rate stands at 52% (2006) with an ambitious target of 100% by 2012 (EDPRS).

used for educational activities possibly reveals that the SPL is better suited for reading and writing activities. Furthermore, all student households spent more hours per week on educational activities with the SPL than the baseline situation. It is also noteworthy that the SPL was used less per evening than the baseline situation, which reveals that households couldn't utilize the light as much as they perhaps would have liked to for the specific activity of education. Many households did express the need for a longer lasting light and an increased number of lights for different rooms and/or activities due to large household sizes.

Also noteworthy is the knowledge and awareness of solar off-grid solutions in all three rural sector communities that were visited. The centralized nature and small size of the nation provides an advantage point for knowledge and technology dissemination. For instance, in Kamonyi, the headmaster and teachers immediately enquired on the possibility for installing larger solar panels that could help power laptops and electricity principally for schools[8].

5.2 The time spent on educational activities with SPL: Issues and Variability

There was a slight aggregate decrease in the time spent on educational activities by all households with the introduction of the SPL. The SPL products were used less on average, which can be explained by the fact that they provided less overall light capacity than existing sources of light, also reinforced by the fact that households did not stop purchasing kerosene and candlelight. Furthermore, households with a lot of occupants and number of rooms needed additional light for other activities.

The time spent on educational activities with SPL products also varied based on a) whether products were used by teacher or students households and b) different SPL products.

First, findings indicate that while there was a general increase in hours spent on educational activities for student households, teacher households spent less time on educational activities after the SPL products were introduced. In addition, student households saw an increase in the number of days they spent on educational activities, increasing the total weekly time spent on educational activities. Although the difference between teacher and student household responses to SPL products is noteworthy, the reason for the difference may also be due to limitations of the survey design.

Secondly, although all four products were primarily used for educational activities, there was a divergence between products with respect to the hours studied per night for households; for examples, for teacher households, only the Solar Home System saw an increase in the hours spent on educational activities per evening.

Overall, survey participants perceived the larger size of the light as a superior attribute compared to the other lights during the initial allocation. The larger SPL products such as the Solar Home System and Uday Mini received substantially less criticism on the quality and brightness of the light than the other two SPL products, which were deemed inadequate for the size of the households. The households, particularly those with the Solar Home System, wanted additional systems to cover all the rooms in their

[8] There are donor projects, which provide laptops for ICT development i.e. One Laptop per Child (OLPC) which was launched in 2008 and has deployed 100,000 laptops to schools. The GoR is targeting to have 160,000 laptops deployed by June 2012.

households. After the introduction of the SPL products, the percentage of household that purchase kerosene fell, however, the percentage of households purchasing candlelight went up for all products. It is worth mentioning that the percentage decrease in the number of households using kerosene unerringly matches the percentage increase in the amount of households using candlelight. This designates candlelight as a supplementary light source to both the SPL and kerosene light source. As there are many rooms and residents per households, it makes sense that candlelight is seen as a cheaper, but dimmer or muted, additional light source. These findings point for the possible demand for scalable and modular products.

The Solar Home System, the only product that saw an increase in time spent on educational activities for both student and teacher households also received the least complaints. This product was used for the longest amount of time per evening amongst the four products. It was described as extremely valuable, particularly as survey participants were able to conduct multiple activities in a communal space.

Similarly, the Uday mini was well received and the brightness of the light produced was considered a strong product feature. There was no impact on time spent on educational activities for students and hardly any for teacher households. The results for the student portion can be attributed to the small sample size.

For households that used the Solar Torch there was an overall decrease on time spent on education, although student households saw an increase in the time they spent on educational activities. The Solar Torch, which also had the lowest usage per night, generated the largest amount of negative feedback from users.

The Reading Light, which was designed specifically for the purpose of reading and studying, did not result in a notable increase in the time spent on educational activities, with a decrease in the time spent on educational activities by teacher households. For student households, there was an aggregate weekly increase in the time spent on educational activities, although the time spent on educational activities per evening decreased by 17 minutes. Some households complained that the reading light was not bright enough or did not last long enough.

5.3 The impact of SPL on Poverty Alleviation

The SPL products had a substantial impact on poverty alleviation by providing households with income saved and access to high quality light, which is useful for studying, strengthening community relationships, increasing the work day and in some instances, providing cell phone charging.

First, the empirical evidence and discussions with survey participants highlight that the most significant impact of the SPL light was the additional income saved. The payback period of the products varied depending on the assumed cost of the product (which can vary). The payback periods for the highest cost assumed a considerable mark-up (multiplier of 2.7) and ranged from 5 months for the Solar Torch (assuming a 2 year life) and 3 years for the Solar Home System (assuming a 10 year life). The seemingly long payback for the Solar Home System must be viewed from the perspective that all battery changes are included in the cost of the product and the high logistical costs of doing business in Rwanda, which can inflate the cost by up to 3 times despite VAT and customs duty exemption. Furthermore, the average expenditure on kerosene and candlelight for the product samples varied significantly, which presents problems in weighing up a direct comparison of payback periods. Yet, with kerosene prices expected to increase annually, coupled with unit manufacturing costs of off-grid solar products falling considerably over the past 10 years, off-grid products are extending

toward an affordable and cost-effective option for rural populations (World Bank, 2010).

Second, the provision of light can be viewed as an important poverty reduction strategy for rural areas. Although the products varied in time spent on educational activities, the fact that they provide for better quality reading and writing light for their education would mean better future prospects for student households. The impact of SPL's on poverty alleviation are considerable, considering that in SSA, approximately 585 million people, which is approximately 70% of the population, have no direct access to electricity. The importance of off-grid options is further emphasized by the fact that 80% of the population with electricity live in rural areas (IEA, 2010). Yet, governments in SSA are inclined to place rural electrification secondary to urban electrification (Acker et al., 1996). Furthermore, it is argued that energy services for the rural poor in SSA are inadequate and grid electrification of rural households is unlikely to succeed (Nygaard, 2009, Wamukonya, 2007). With the widespread expansion of grid electricity networks in SSA deemed implausible in the near future, the region will need to see alternative solutions to access to energy services for poverty alleviation and development opportunities.

Third, the phone charging ability of the Solar Home System provides an important contribution to communication in rural areas. For instance, the importance of cell phone charging capabilities was emphasized in Rulindo, where the headmaster described the one hour bus journey to the charging point (with a fee of 300RW) where the cell phone is charged at 100RW for an approximate day worth of cell-phone use. This also reduces the financial purchase burden of cell phone charging. However, the Solar Torch, which comprises a cell phone charger, received complaints on battery life and its cell phone charging abilities.

Fourth, familial and rural development was underscored during the discussion with households. The impact of the lights on the community to help foster and improve the cooperative spirit of the village was shared. In addition, as the light can be used in a communal space, many family members can benefit from the light. One participant noted the ability to focus on other 'development projects' such as spending the income saved on other investments. The potential for off-grid solar for fostering potential income generating activities is prevalent in literature, discounting kerosene and candle light as inadequate for close work and activities such as reading (Nieuwenhout et al., 1999, Cabraal et al., 2005).

Fifth, the light also enabled female members of the households who worked as farmers or were self-employed to work longer hours. For example, women were able to stay out on the farms longer as they no longer had to leave before dark to prepare dinner. Additionally, lighting also increase the number of productive hours and enables people to work at night (Cabraal et al., 2005).

Sixth, households emphasized the impact on health and safety during the discussion. They expressed the dangers of kerosene and candlelight, with some parents pointing out that students can cause accidents while they are studying if their paper catches fire or if they fall asleep. The glass from the lantern breaking also is considered dangerous. In addition, the smoke caused by kerosene was acknowledged as being very unhealthy; many households lack sufficiently sized windows or adequate airways to clear of the smoke in an effective way. Safety from the standpoint of being able to see who is at the door in the evenings and possessing a reliable and safe light source during emergencies, i.e. when children are sick at night, provides further justification for replacing kerosene with the SPL for households. Health benefits, such as reduced smoke, were highlighted by women.

5.3.1 Conclusion

The main contribution of this work is providing empirical data on the impact of SPL products on the time spent on educational activities for student and teacher households, which has not been quantifiably investigated in literature albeit a small number of studies. The study also provides information on the socio-economic response of these households after SPL adoption in relation to their baseline situation. The study provides valuable information on the use of light, as well as economic indicators such as income saved and willingness-to-pay.

There exists some variation on the results depending on the type of household (teacher or student) and the product provided to the household. Notwithstanding, the data identifies an overall increase in time spent on educational activities per week for students. Outcomes for teacher households, however, depend on the type of product that was introduced. Lastly, the study identifies the Solar Home Systems (SHS) was preferred and provided the most advantageous lighting service in terms of time spent on education, as well as providing additional benefits such as cell phone charging.

6 Recommendations

The provision of the SPL products provides households with the ability to have a high quality light, arguably provides educational benefits, and is an economic alternative to kerosene. I propose further research on developing private sector's provision of SPL lighting and potential solutions to end-user financing within the Rwandan context.

6.1 Private sector's role in the provision of SPL lighting

There is a wide array of literature that explores the potential for off-grid lighting services for the rural poor in developing nations; also known as the 'Bottom of the Pyramid' (BoP) that live on less than $2 a day. The literature argues that the best way to meet the needs of this economic segment is to mobilize a profit driven market-based approach (Prahalad, 2002) especially given the high initial cost of SPL products.

However, the execution and distribution of solar technologies in SSA by private actors has been sluggish and problematic partly due to a lack of financial resources, little know-how, the inability to develop an extensive distribution value chain and a lack of capacity for maintenance, repair and raising awareness (World Bank, 2010, Wamukonya, 2007). The proven environmental, health and cost benefits brought about by changing from fossil fuels to off-grid solar lighting has not yet resulted in far-reaching availability, despite the large efforts invested by governments and multilateral and bilateral institutions in the introduction of this technology.

Most of the projects did not establish institutional and commercial viability and they ultimately lacked mechanisms for equipment maintenance, sources of credit and expertise, and incentives for continued operation and expansion
For this reason, the dissemination and sustainability of the product must be addressed; increasingly such off-grid technologies are introduced and disseminated through market approach rather than a traditional donor project approach. The donor approach is problematic in that it doesn't address the sustainability of the SPL provision; the BoP cannot afford the money the product demands and once the project is terminated, the continued provision, technical and financial support cannot be maintained.

More specifically, Rwanda faces a number of strategic issues when it comes to establishing a market for SPL products; it is a small landlocked country that faces high logistical costs of importing goods, the private sector is relatively limited and there exists a shortage of trained professionals in the workforce. Yet, the GoR is providing an opportunity for collaboration between the private sector, public sector and financial and research institutions; creating a constructive business-government dialogue. However, progress relies on the presence of the firms in the local region with daily interactions to ease communication difficulties that may arise from differences in social and cultural business interactions. As a Philips representative, my physical presence to both the SACCO and MINEDUC allowed me to gain greater clout, expand my network and improve the effectiveness and momentum of my research. Due to the small size of nation, it is easy to gain an observable presence by potential private sector and public sector partners. Thus, the possibility to capture synergies in the SPL market and government policy in Rwanda is substantial due to the ease of access to all stakeholders.

The GoR strongly supports the shift from kerosene to solar for poverty reduction and educational goals. Therefore, opportunities within the GoR for ministry level financial or marketing support need to be explored along with other financing opportunities for Philips Lighting through multilateral agencies, NGO's and tenders. On the part of the Teacher's SACCO and Ministry of Education, this partnership helps improve the lives of the rural poor by providing efficient lighting services that provide income saved, reduce health risks and improve quality of education for both teachers and students. The cooperation with ministries such as the Ministry of Education can help promote the use of light, as well as remove cultural and legal obstacles which could otherwise complicate the sale of solar lamps. There also exists the opportunity of carbon credit financing. Here, the application and registration processes need to be explored within the value chain.

Furthermore, agencies such as the Rwanda Utilities Regulatory Agency (RURA,) who are keen to standardize quality and product safety standards for SPL products could help remove the entrance of poor quality products that can ruin the market. Government procurement could also provide greater opportunities for raising awareness on SPL products in rural regions. MNE's, such as Philips, can help develop market conditions through the provision of capacity building assistance in standards and practices, and by coordinating regular meetings between key stakeholders.

An in-depth evaluation of existing commercial networks is necessary to map the value-chain or distribution of the SPL products to investigate whether they can provide an affordable, sustainable and scalable enterprise opportunity for private sector SPL providers in Rwanda. For example, solar lighting requires households to account for maintenance and servicing. Therefore, market entry must address a clear after-service that is affordable and available in the area. The delivery system of the after-service must be commercially viable for the dealers that are performing the repairing and servicing. The issues of warranty, service and repair were of particular concern to the teachers and the Teacher's SACCO.

6.2 Issues of Financing

The subject of affordability is a significant issue for SPL's and due to the considerable upfront cost of solar lighting systems, consumer financing continues to be the only option to providing increased access to energy products. Rural households are accustomed to purchasing kerosene in small incremental payments on a daily, weekly or monthly basis. For this reason, the upfront cost of the SPL remains a prominent

obstacle for SPL providers despite its numerous social and economic benefits over kerosene. As

The Teacher's SACCO provides low interest Solar Energy Loans and reduces the end-user financing barrier. I propose further investigation of all the SACCO's in Rwanda. With strong government support, this could be a major penetration point for this market, reducing the major hurdle of end-user financing. Therefore, further research needs to be conducted on the way in which the value chain can be optimized in terms of end-user financing via the SACCO, addressing challenges to importer financing and gaining overall market presence in this chain.

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Annex A Rwanda

Vision 2020 and MDG Goals

Vision 2020 places great emphasis on developing a wide range of professional and technical skills with the broader vision of turning Rwanda into a knowledge-based economy. The removal of tuition fees under the 'Nine Year Basic Education' programme coupled with strong donor alignment has led to considerable gains in this area (MINEDUC, 2008). Surveys indicate that net primary enrolment rate increased from 74% to 86% between 2000/01 and 2005/06 – highlighting that Rwanda is on track to achieving universal primary enrolment by 2015 (GoR, 2007)[9].

Rwanda, like most developing nations, has also committed itself to reaching the Millennium Development Goals (MDGs). Despite the difficult post-crisis environment, Rwanda's economy has recorded macroeconomic stability with robust real GDP growth since 2000 (the period of 2001-2006 saw the annual rate at 6.4%) (GoR, 2007).

However, high GDP growth rates have not translated into progress in the MDG goal of halving the poverty headcount of 1990 by 2015; the rate has fallen marginally from 60.4% in 2000/01 to 56.9% in 2005/2006 (Oxford Policy Management, 2007). The average poor person's consumption is about 150RWF/day and has only increased by about 2% in the past five years (GoR, 2007). In the absence of significant export earnings and the high cost of trade, the need to invest in infrastructure has been identified as a priority in order to meet the targets set in Vision 2020 and the MDGs (World Bank, 2007b).

Primary energy trends and policy

One major problem that the Rwandan economy is facing is that energy imports use more foreign exchange reserves than exports. For this reason, the GoR has defined several objectives and targets in order to tackle the persistent problem of (rural) energy poverty in the country including increasing access to grid electricity and decentralized energy sources. Projects to increase electricity capacity include construction of thermal generation plants, methane from Lake Kivu, hydropower projects, a Uganda-Rwanda oil pipeline project, oil exploration, gas to liquid plants and geothermal potential exploration (NEP 2009).

In addition, Rwanda faces very high electricity costs; in 2011 the cost of electricity was 0.21US$/kWh (+VAT) for domestic customers, and 0.19US$/kWh (+VAT) for large commercial and industrial consumers. This makes it one of the highest tariffs in SSA and almost double the cost in the region (MININFRA, 2009). The per capita electricity use is one of the lowest in the world and the capital, Kigali, accounts for more than 70% of the total national electricity consumption. Some plans to reduce these costs include policies to reduce distant from the grid via 'grouped settlements' (National Urban Housing Policy 2008) and plans to build a railway to connect Kigali to Dar-es-Salaam (NEP 2009).

For these reasons, grid electrification is a challenge; it requires substantial investment and extensive maintenance; the costs per unit are high and, consequently, the poor consumers in rural areas cannot afford it unless it is subsidized. Yet, the EDPRS

9 Key indicators include increased literacy rates and completion rates; currently, adult literacy stands at 65% of the total population aged 15 or older (up from 52% in 2000/01), the completion rate stands at 52% (2006) with an ambitious target of 100% by 2012 (EDPRS).

targets for 2008 – 2012 aim to increase access to electricity from the 6% to 16% and electricity generation from 60MW to 165MW (MINECOFIN, 2007). The government has a number of projects to meet this target including the Rwanda Electricity Access Scale-up and Sector Wide Approach (SWAP) Development Project (NEP, 2009). Rwanda has also initiated an Electricity Access Roll-out Programme, financed by the World Bank, that aims to attain a national electrification rate of 16% by 2012 and 50% electricity by 2020, higher than the initial 35% target in Vision 2020. In addition, Vision 2020 specifically sets an ambitious target to increase access of population to energy to at least 60% by 2020 (GoR, 2000). Furthermore, The GoR aims to decrease the contribution of biomass use down to 50% by 2020 from the current 85% (GoR , 2000).

Annex B Baseline Survey

Baseline Survey
Selen Kesrelioglu
Philips Lighting Survey
E mail Address: selen.kesrelioglu@philips.com

1. **Household Roster and Education**

Name of Person administering Survey	District of Origin Rulindo...........1 Kamyoni.........2 Kirehe 3	Teacher or Student Household Teacher ....1 Student 2	Date & Time of Interview	Name of Person Being Interviewed	Product Provided Solar Home System.............................1 Uday Mini.........................2 Reading Light...................3 Solar Torch.......................4	Household ID CODE
Selen Kesrelioglu			Date: / / 2011			

	1. I would like to make a complete list of all the people who normally live and eat their meals together in this house beginning with your immediate family and then the extended family. FIRST COMPLETE LIST OF NAMES OF HOUSEHOLD MEMBERS. THEN ASK Q2-10FOR EACH HOUSEHOLD MEMBER BEFORE GOING TO THE NEXT MEMBER. **NAME**	2. SEX **M**ale **F**emale	3. RELATIONSHIP TO HEAD: HEAD……………………………1 WIFE/HUSBAND…………………2 CHILD/ADOPTED CHILD……….3 GRANDCHILD…………………….4 NIECE/NEPHEW…………………5 COUSIN……………………………6 FATHER/MOTHER………………7 SISTER/BROTHER………………8 SON/DAUGHTER-IN-LAW……..9 BROTHER/SISTER-IN-LAW……10 GRANDFATHER/MOTHER……11 FATHER/MOTHER-IN-LAW…..12 OTHER RELATIVE………………13 SERVANT ……………………….14	4. How old is [NAME]? > 12, »Q5 <5, » NEXT MEMBER 5-12, » Q6 **YEARS**	6. Is [NAME] attending school now? **YES..1** **NO…2**	7. What was/is the highest level completed by [NAME]? NONE…………………1 PRIMARY……………2 SECONDARY……….3 UPPER SECONDARY……….4 DIPLOMA/FIRST DEGREE……………..5 MASTERS or	8. What is the main activity of [NAME]? FARMING…………..1 FISHING…………….2 CHARCOAL………..3 FIREWOOD………..4 TIMBER……………..5 EMPLOYEE………..6 OWN BUSINESS…7 UNPAID FAMILY HELPER……………..8 HOUSEWIFE……….9 STUDENT………….10 NOT ACTIVE………11 TEACHER………….12	9. How many rooms do you have in your home?
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								

2. <u>Current Lighting Practices</u>

2.1 Daily routine based on time spent in daylight

What time does it get light	
What time does it get dark	
What time do you wake up	
What time do you sleep	

2.2 Sources of light and frequency of use

Candles:	
number purchased a month	
cost per month	
Average hours of use per night	
Days used per week	

Kerosene Lantern:			
Number of lanterns in household			
How many lanterns do you use every evening:			
How often do your purchase kerosene (choose one)	Daily	weekly	monthly
Amount purchased (RWF)			
cost per litre (RWF)			

Average hours of kerosene use per night	
Days used per week	
Time spent obtaining light from source hrs/week	
Distance to source (km)	

What percentage of your income do you spend on light?	

2.3 Use of light

What activity do you spend the most time on with the light?	

What do you use the light for primarily?	**hours/evening**
Studying/Educational Activities (i.e. reading/grading)	
Cooking	
Eating	
Going outside (collecting water, food, toilet)	
Recreational activities (spending time with family, games)	
Work related activities	
Other…	

3. Education

Questions for parent/guardian	
How many members of your household are currently enrolled in school?	
What are the school hours?	
How does the child get to school?	
How far is the school? (hours or kms)	
How many days a week do children go to school?	
How many days a week do children study	
What time do your children study and do revision	
How many hours at night do children study with the light?	
Where do children study?	Home (inside)

Question for one student in household

Name of Student	
Sex	
Age	
What time do you wake up?	
What time do you sleep?	
What are your school hours?	
How do you get to school?	
How far is your school (in hours)?	
Do you have an exercise book (Yes/No)?	
Do you have a reading book? (Yes/No)	
Does your school have a library with reading books? (Y/N)	
If yes, do you bring reading books home (Y/N)	
Apart from school books, do you have books, or other materials that you can read at home? (Y/N)	
How many days a week do you go to school	
How many days a week do you revise/do homework/study?	
How many hours a day do you revise/do homework/ complete other educational activities?	
Between what hours do you usually revise/do homework/complete other educational activities?	
How many hours a night do you study at night with kerosene/candle light (if at all)	
Is there electricity at school?	
Where do you study?	Home (inside)

ons for Teachers	
How many years have you been a teacher	
What are your teaching hours	
How many additional hours do you work a day to prepare lessons/grade/additional work for school	
Where do you prepare classes/grade work	

What time do you grade students work	
What time do you prepare your lessons	

Annex C Follow-up Survey

Follow-up Survey
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1. Household ID/Interviewee

Name of Person administering Survey	District of Origin	Teacher or Student Household	Date & Time of Interview	Name of Person Being Interviewed	Product Provided	Household ID CODE
	Rulindo..........1 Kamyoni.........2 Kirehe 3	Teacher ....1 Student 2			Solar Home System............................1 Uday Mini.........................2 Reading Light...................3 Solar Torch.......................4	
Selen Kesrelioglu			Date: / / 2011			

4. Current Lighting Practices

4.1 Daily routine based on time spent in daylight

What time do you wake up?	
What time do you sleep?	

4.2 Sources of non solar light and frequency of use

Did you use any other light source during this period? (Yes/No)	
If Yes, answer which light source below. If no, move to next section	

Candles:	
number purchased since installing solar light	
Average hours of candlelight used per light since installing solar light	
Days used in a week since installing solar light	

Kerosene Lantern:	
Amount of Kerosene purchased since installing solar light (RWF)	
Average hours of kerosene use per night	

Days used per week	

4.3 Frequency of use

How many nights a week do you use the product	
On the days used, for how many hours did you use the product a day?	
How many days a week do you charge the battery	

4.4 Use of Solar Light

What activity do you spend the most light on?	

What do you use the light for primarily?	**hours/evening**
Studying/Educational Activities (i.e. reading/grading)	
Cooking	
Eating	
Going outside (collecting water, food, toilet)	
Recreational activities (spending time with family, games)	
Work related activities	
Charging cell phone	
Other…	

What percentage of your income do you spend on light?	

4.5 Functionality of solar light

Did the light stop working during the period? (yes/no)							
Did the battery stop working during the period? (Yes/No)							
Did the solar panel break during period ? (Yes/No)							
What are the main problems you experienced with the torches? Circle all revelant	failure of LED/CFL light	Failure of battery	Failure of panel	Failure of wiring	installation difficulty	not bright enough	doesn't last long enough
Did you experience any other problems with the functionality of the product? If yes, please describe							

4.6 Light quality

How is the light level? (circle one)	Prefer more light	OK	Prefer less light

5. **Education**

5.1 Questions for Parents/Guardian

How many days a week do children study?	
During what hours do your children study/do homework?	
How many hours after dark are spent on educational activities	
Does your child use the solar light for studying?	
if yes, how many hours a day do they use the light for studying?	
Have you witnessed an change in the level of education in your child? (circle one)	better

5.2 Question for student

Name of student	
Age	
How many days a week do you revise/do homework/study?	
How many hours a day do you revise/do homework/ complete other educational activities?	
How many hours a night do you study with the solar light (if at all)	

5.3 Question for Teacher

How many additional hours do you work a day to prepare classes/teacher meetings/parent meetings and other issues				
When do you grade students work	Mornign before school	At recess	After school before it gets dark	After school when it is dark with light
When do you prepare your lessons	Mornign before school	At recess	After school before it gets dark	After school when it is dark with light
Have you shown the product to other members of your community (Yes/No)				

How can these lights benefit your community?	

6. **Willingness to Pay**

6.1 Willingness to pay for product

Would you like to keep the product (Yes/No)			
If No, please specify why not and your main concern/problem with SPL product:			
If Yes, continue with the below questions			
Would you pay to keep the product	Y	N	
How would you like to pay for the product? (circle one)	daily	weekly	monthly
How much would you be willing to pay for the product until it stops working (in your preferred payment term)?			
What is the main reason you'd like to keep the product?			

6.2 Loans (For Teachers ONLY)

If the SACCO provided a loan for the product would you buy it and have an amount deducted from your monthly fees until the product is paid for? (Yes/No)	
How far do you live from the local SACCO office?	
How often do you go to the SACCO office?	
Have you show your solar lamp to people in your community? (y/n)	
If yes, what is the response:	

Annex D Product Analyses: Solar Home System

Impact on Education

Despite cell phone charging abilities, the Solar Home System was primarily used for studying and educational activities. In fact, time spent on educational activities increased by 35 minutes.

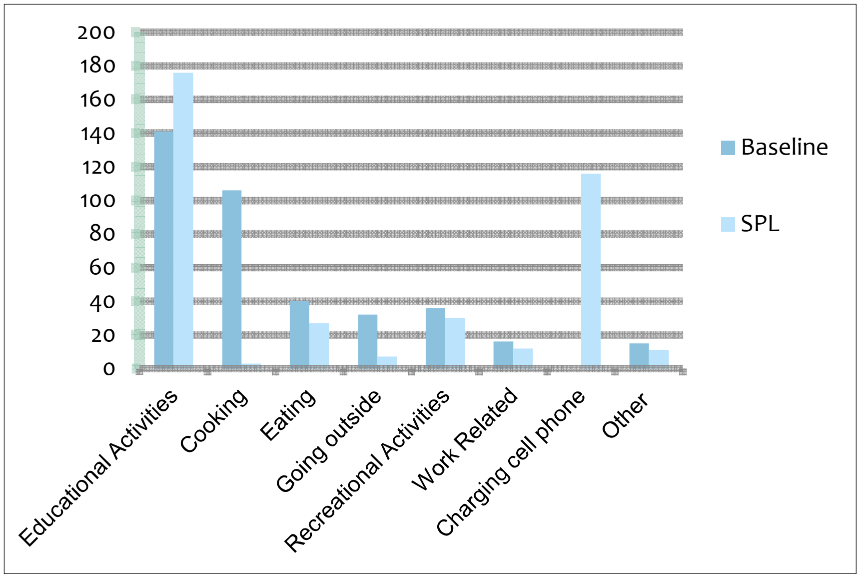

Figure 9: Comparison of time spent on activities with light for the Solar Home System (minutes per evening)

The impact on time spent on educational activities for students was considerable with the Solar Home System. The average time spent on educational activities increased on average as seen in *Figure 9*. Apart from Kirehe, which saw a percentage decrease in the hours studied per night, the remaining two sectors of Rulindo and Kamonyi saw a respective 75% and 133% percentage increase in hours studied per night. Furthermore, there was an increase in the number of days studied per week from 5.83 to 7, showing an added increase in the overall time spent on education per week. Noticeably, the light was not used at all for cooking, indicating that the Solar Home System was not installed in the kitchen. The charging abilities of this product were also used on average almost 2 hours a day.

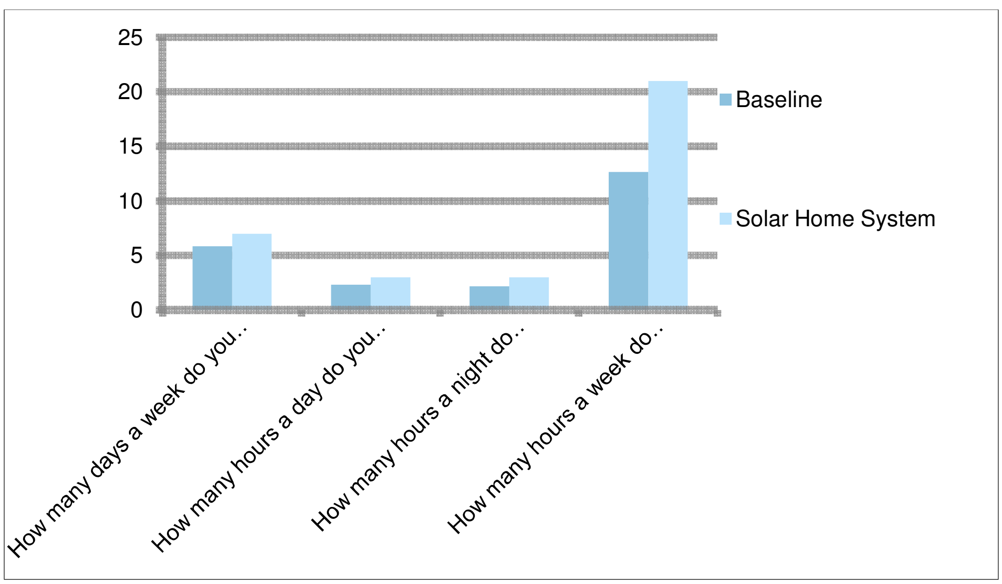

Figure 10: Comparative use of light for educational activities by students for the Solar Home System

Teachers also observed an increase in the time spent on educational activities by 33 minutes on average per night.

Economic Impact

In the group discussion, the households emphasized the positive impact of the Solar Home System on their income. Households in this sample spent 15.18% of their total income on light with a purchase burden of 1 hour a week, or about a 4km distance. Household expenditure on lighting decreased from 15.18% of their income spent on light to 6.78% spent on light.

The average amount spent on kerosene and candles before and after the installation of the Solar Home System can be seen in *Figure 11*.

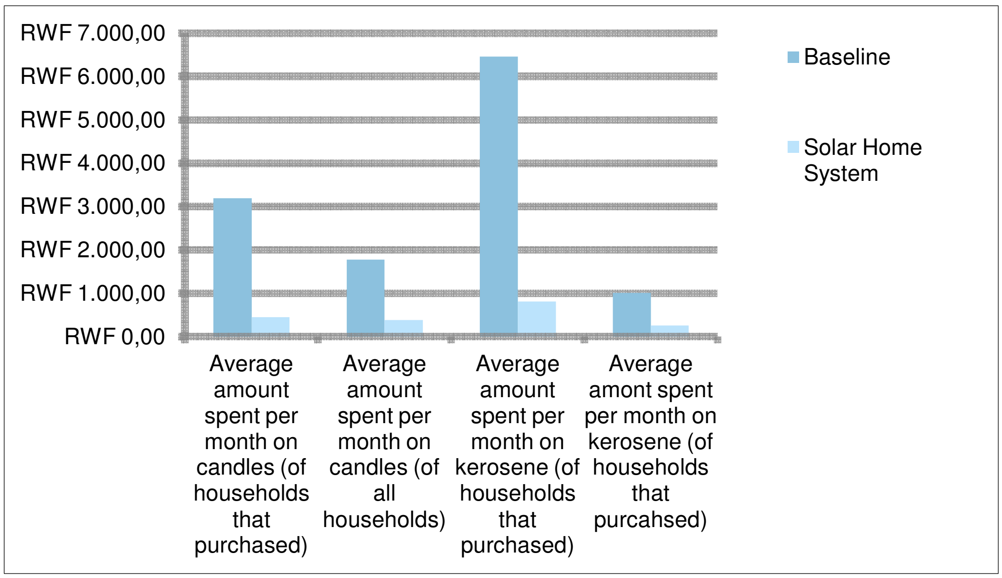

Figure 11: Comparative average monthly expenditure by households for kerosene and candlelight for the Solar Home System

Of the interviewed households, 56% purchased candles and 61% purchased kerosene lanterns before the solar lantern was used. Although the percentage of households using kerosene decreased from 61% to 21% after the installation of the Solar Home System, candlelight saw an increase from 56% to 75%. Households substituting kerosene use for candlelight as a supplementary light source is one explanation. However, despite this increase, the amount spent on candles per household decreased substantially. The same is true for Kerosene use.

Willingness to pay

All households responded that they would like to keep the product and would be willing to pay for the product, with a preferred payment term of monthly. When asked how much they would be willing to pay for the product until it stops working, the average was 963 RWF/month, with teacher households willing to pay more on average.

Payback period

The payback period for the solar home system assumes a product life of 10 years and does take into account the cost of 4 battery replacements over the 10-year life of the product.

The payback period for the product, assuming a Freight-on-board (hereafter cited as FOB) price, was 1 year 2 months. However, due to the high transport and logistical costs associated with Rwanda, the payback period for the FOB*2 and FOB*2.7 were also calculated. The latter is a more realistic estimate for the local conditions. Therefore, the payback period assuming a mark up of double the FOB is 2 years 4 months and for FOB*2.7 it is 3 years. This means that the product will at most pay itself in 3 years, providing an additional 7 years of lighting needs without any expense.

Annex E Product Analyses: Reading Light

Impact on Education

The Reading Light was mostly used for studying and educational activities by both student and teacher households. The light was used for educational activities for 1 hour 40 minutes an evening on average.

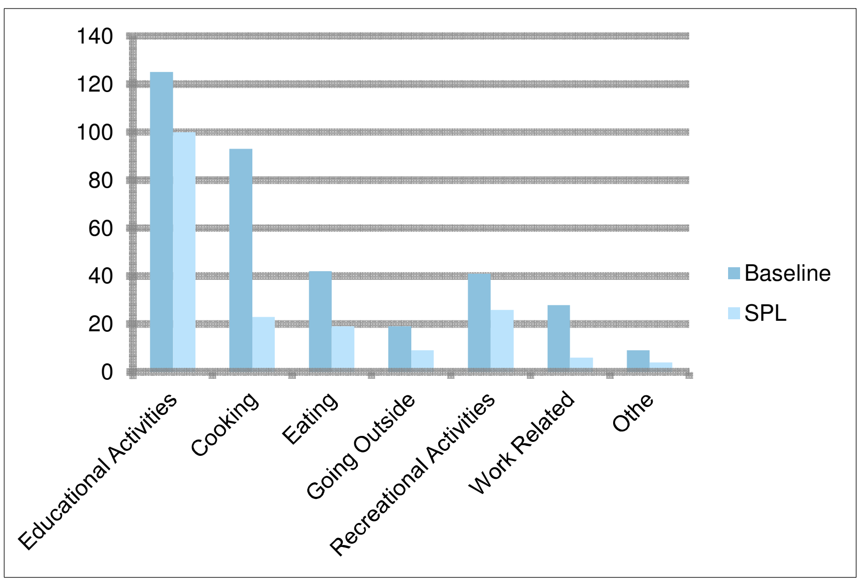

Figure 12: Comparison of time spent on activities with light for the Reading Light (minutes per evening)

The impact on time spent on educational activities for students did increase with the Reading Light. However, the average hours studied per night decreased by 17 minutes . However, students were able to study more days a week, which observes an aggregate weekly increase in time spent on educational activities.

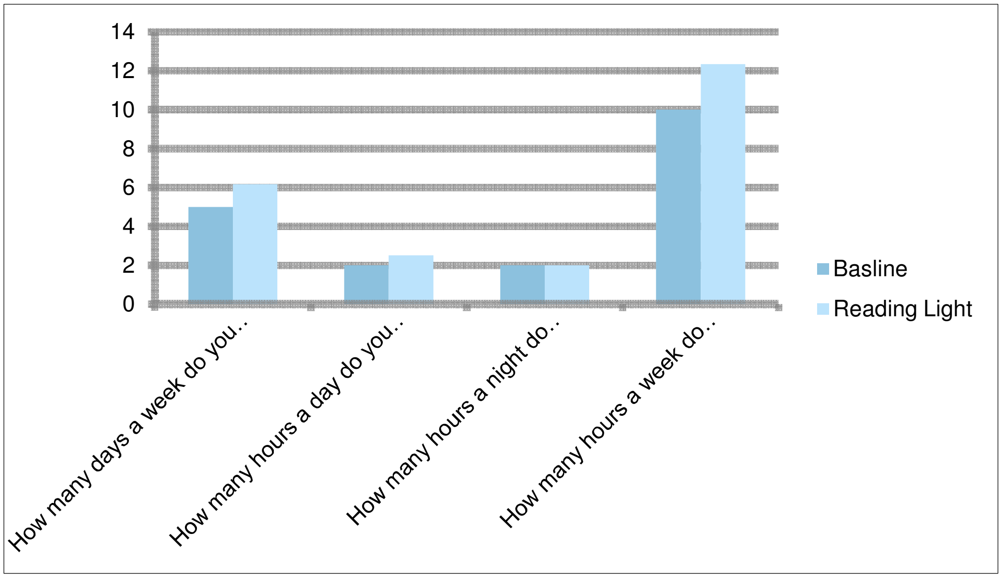

Figure 13: Comparative use of light for educational activities by students for Reading Light

On the other hand, the average amount of time spent on educational activities by teachers at home decreased by 42 minutes on average.

Economic Impact

There was a positive impact on income after the introduction of the Reading Light with a decrease in the percentage of their income spent on light from 19.33% (baseline) to 12.33%.

The percentage of households using kerosene decreased from 72% to 56% after receiving the Reading Light, however, the percentage of households purchasing candle light increased from 33% to 47%. Furthermore, *Figure 14* illustrates the substantial decrease in the monthly expenditure on candles and kerosene with the introduction of the light.

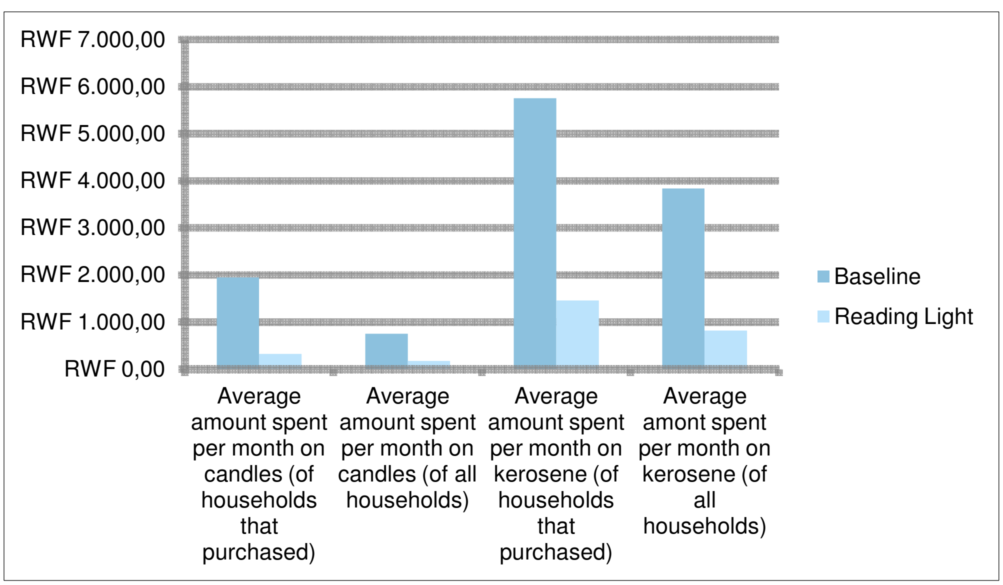

Figure 14: Comparative average monthly expenditure by households for kerosene and candlelight for the Reading Light

Furthermore the households in this sample travel 3 hours a week on average to obtain the kerosene or candles and live approximately 3km from the point of purchase.

Willingness to pay

All households responded that they would like to keep the product and all but one would be willing to pay for the product. All households' preferred payment term was monthly, with the exception of one teacher household preferring daily payment. The average WTP was 897 RWF/month, with student households willing to pay more on average than teacher households.

Payback period

The payback period assumes a product life of 10 years and includes the cost of 14 additional NiMh rechargeable batteries will last 1 year and 5 months [10] and will cost 1800 RWF for a pack of two batteries.

The payback period for the product assuming a FOB price is 4 months, using the average annual payment of all households on kerosene and candle light use for this sample. The payback period assuming a mark up of * 2 is 8 months and 11.5 months for the inflated price of 2.7 times the FOB price.

Annex F Product Analyses: Solar Torch

Impact on Education

Figure 15 illustrates that the Solar Torch was predominantly used for educational activities. The light was used for educational activities for 1 hour 44 minutes an evening on average.

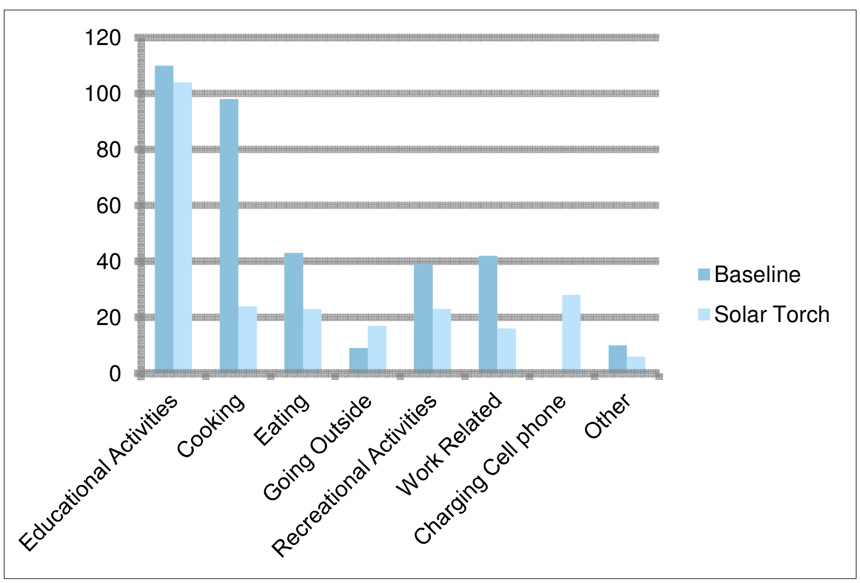

Figure 15: Comparison of time spent on activities with light for the Solar Torch (minutes per evening)

[10] Specifications state the battery can be charged 500 times

The impact on time spent on educational activities for students did increase with the Solar Torch. Students were able to study more nights a week and able to study more on average at night

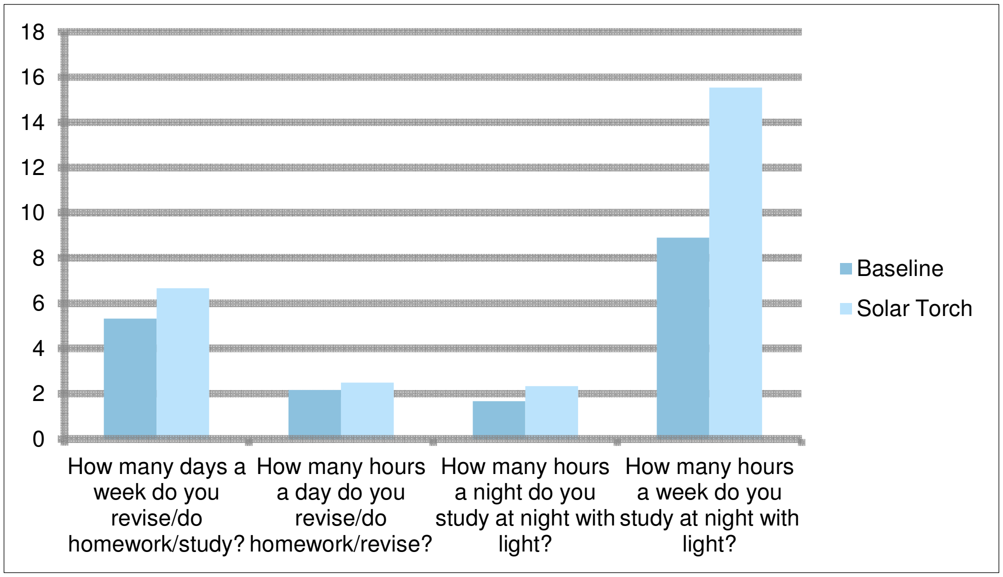

Figure 16: Comparative use of light for educational activities by students for the Solar Torch

However, the average amount of time spent on educational activities by teachers at home decreased by 37 minutes on average.

Economic Impact

This sample saw a peculiar increase in the percentage of household expenditure spent on light after receiving the light from 15.8 to 19.1%. Furthermore, while the percentage of households using kerosene decreased from 80% to 40% after receiving the Solar Torch, there was an unexpected 56% increase in the amount spent on kerosene (of households that purchased); this irregularity can be viewed in *Figure 17*. However the average expenditure of kerosene for all households saw a decrease.

The percentage of households purchasing candle light increased from 47% to 80%, however, the amount spent on candles decreased.

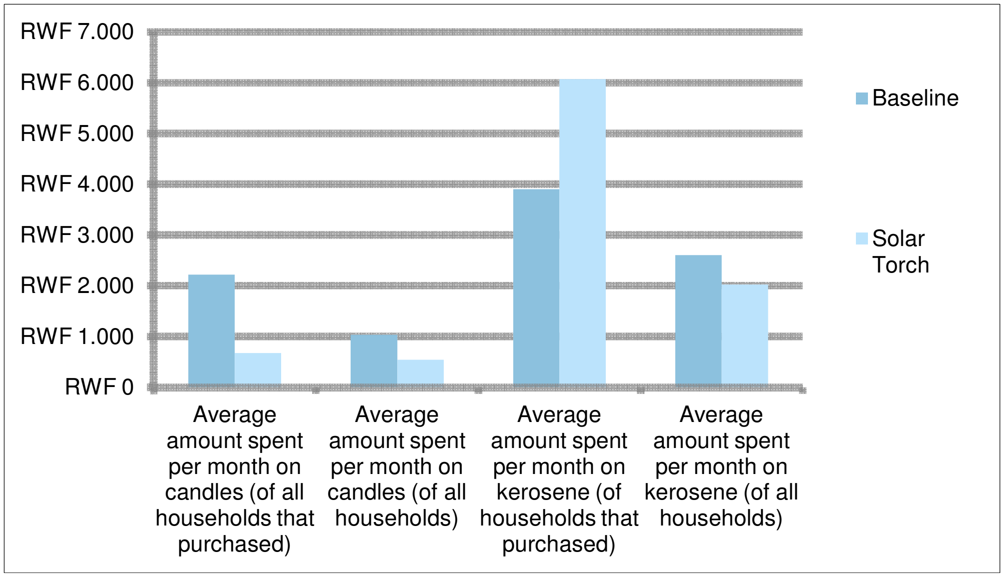

Figure 17: Comparative average monthly expenditure by households for kerosene and candlelight for the Solar Torch

Willingness to pay

All but one household responded that they would like to keep the product and all but one would be willing to pay for the product. All households' preferred payment term was monthly and would be willing to pay for the product 1,2489RWF/ month until it stops working, with teacher households willing to pay more on average.

Payback period

The payback period assumes a product life of 2 years. Despite the LED lamp that can last 10 years, we assume that the users cannot replace the battery, which lasts 2 years on average. For this product, we didn't assume any battery changes due to the difficulty of its reassemblement.

The payback period for the product assuming a FOB price was only 2 months. The payback period assuming a mark up of * 2 is 4 months and 5 months for FOB*2.7 price. This means that the product will at most pay itself back in less than 5 months.

Annex G Product Analyses: Uday Mini

Impact on Education

The Uday Mini was mostly used for studying and educational activities. The light was used for educational activities for 2 hours 12 minutes an evening on average.

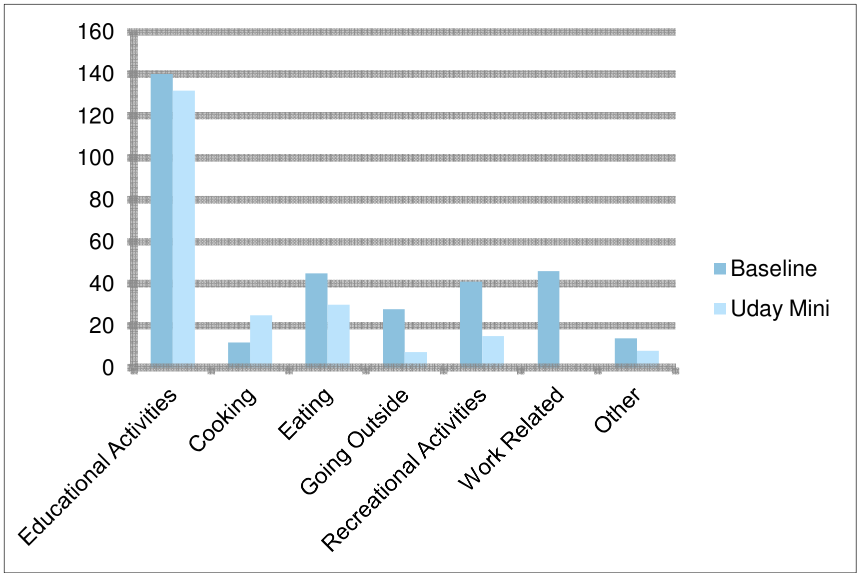

Figure 18: Comparison of time spent on activities with light for the Uday Mini

There was no impact on time spent on educational activities for students in respect to days studied per week and hours per evening. However, this may be due to the fact that only two students participated in the study for the Uday Mini, with only one student available to participate in the second survey.

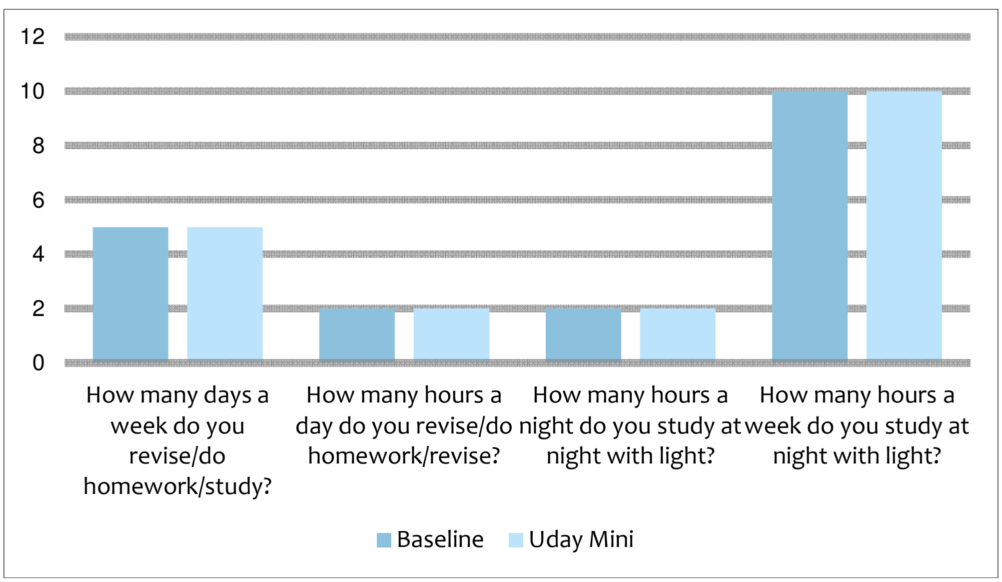

Figure 19: Comparative use of light for educational activities by students for the Uday Mini

The average amount of time spent on educational activities by teachers at home remained approximately the same at 2 hours.

Economic Impact

The overall positive economic impact for the Uday mini was the most significant amongst all products. This particular sample saw the great decrease in the average

amount spent per month on candles and kerosene light as can be observed in *Figure 20.*

The baseline percentage of income spent on light is approximately 17% for this sample and the monthly expenditure on kerosene was the highest for this sample, averaging at 8,945 RWF. It is perhaps for this reason that this sample saw a significant reduction on the percentage of income spent on light to 9.3% after receiving the Uday Mini.

Furthermore the percentage of households using kerosene decreased from 67% to 50% after receiving the Uday Mini and the percentage of households purchasing candlelight increased from 33% to 58%.

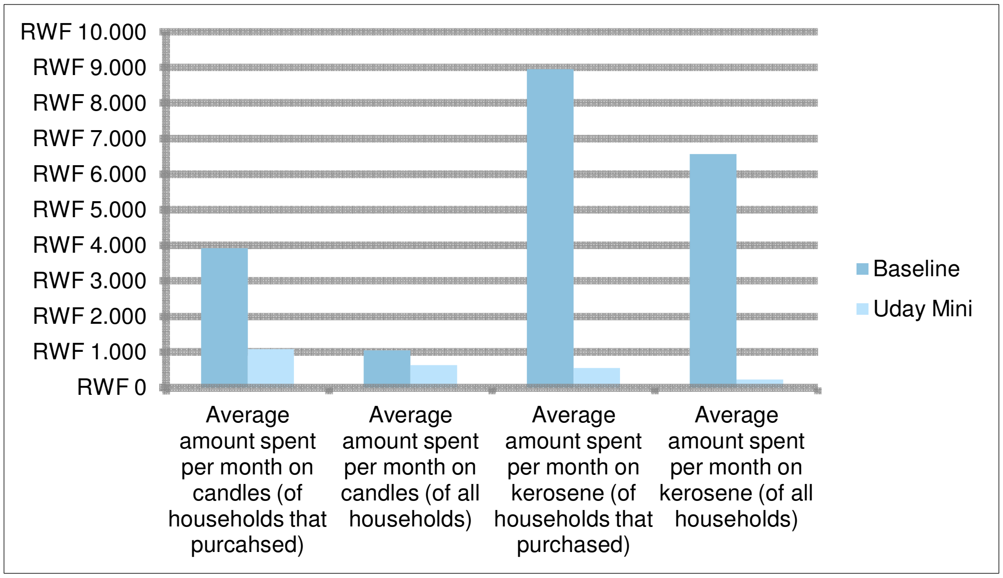

Figure 20: Comparative average monthly expenditure by households for kerosene and candlelight for the Uday Mini

Willingness to pay

All households responded that they would like to keep the product and preferred a monthly payment schedule. The willingness to pay was 1,126 RWF/month, with teacher households willing to pay more on average.

Payback period

The payback period assumes a product life of 10 years. This includes two light replacements and four battery replacements as part of the cost of the product.

The payback period for the product assuming a FOB price was 5 months, using the average annual payment of all households on kerosene and candle light use. The payback period assuming a mark up of * 2 is 10 months and 1 year 2 months for the inflated price of 2.7 times the FOB price. Although the Uday Mini's price is comparable to the Solar Home System, the considerably higher average monthly expenditure on lighting can account for the earlier payback period.